TRANSAMERICA DELAVAL, INC. EMERGENCY DIESEL GENERATORS OWNERS GROUP

Generic Topical Report

TDI-EDG-001-A

Basis for Modification to Inspection Requirements For Transamerica Delaval, Inc., Emergency Diesel Generators

Approved by the U.S. Nuclear Regulatory Commission March 17, 1994

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Appendix A - Licensing Submittal on Behalf of the Transamerica DeLaval,Inc., Owners Group for Review of Licensing Conditions Imposed by NUREG-1216. This report is dated November 30, 1992, and was submitted to the NRC by December 8, 1992 letter.

Appendix B - Licensing Submittal on Behalf of the Transamerica DeLaval,Inc., Owners Group for Review of Licensing Conditions Imposed by NUREG-1216, Revision 1. This report was submitted to the NRC by May 3, 1993 letter.

Appendix C - Generic Licensing Submittal No. 2 for Emergency Diesel Generators Conditions of License for Utilities with Enterprise Engines. This report was submitted to the NRC by December 7, 1993 letter.

Appendix D - TDI Owners Group December 21, 1993 letter to the NRC. This letter provided additional information regarding available outage windows for engine teardown and overhauls and fast start capability.

UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555-0001

MAR 17 1994

Mr. R. C. Day
Duke Engineering & Services, Inc.
TDI Diesel Generators Owners' Group
Clearinghouse
230 South Tryon Street
P. O. Box 1004
Charlotte, North Carolina 28201-1004

Dear Mr. Day:

SUBJECT: SAFETY EVALUATION, INSPECTION REQUIREMENTS FOR TRANSAMERICA DELAVAL, INC. DIESEL GENERATORS (TAC NO. M85325)

The Transamerica Delaval (TDI) diesel generators Owners' Group (Owners' Group) submitted proposals on November 30, 1992 (Reference 1 in the enclosed Safety Evaluation) and December 7, 1993 (Reference 2), recommending removal of licensing conditions imposed as part of a technical resolution to address concerns regarding the reliability of the TDI emergency diesel generators (EDGs) following the crankshaft failure at Shoreham in August 1983. The technical resolution involved implementation of Phase I and Phase II programs as identified in NUREG-1216 (Reference 3). The Phase I program focused on the resolution of known engine component problems that had potential generic implications, while the Phase II program focused on the design review of a large set of important engine components to ensure their adequacy from a manufacturing standpoint, as well as operational performance. At that time, the staff concluded that these components merited special emphasis in the area of load restrictions and/or maintenance and surveillance. The 16 major components which were identified included connecting rods, crankshafts, cylinder blocks, cylinder heads, piston skirts, and turbochargers. Engine load restrictions were addressed in the plant Technical Specifications, license conditions, engine operating procedures and operator training, as appropriate, for five of these components. The most critical periodic maintenance/surveillance actions for these components were incorporated as license conditions.

On the basis of substantial operational data and inspection results the Owners' Group provided information in References 2 and 3 to demonstrate that the special concerns of NUREG-1216 are no longer warranted. The Owners' Group stated that the TDI EDGs should be treated on a par with other EDGs within the nuclear industry and subjected to the same standard regulations, without the special requirements of NUREG-1216. In addition, the Owners' Group stated that this action will improve availability of the engines for service, especially during outages, while maintaining current reliability levels.

The NRC staff and its consultants at Pacific Northwest Laboratories (PNL) have completed a review of the operational data and inspection results contained in the Owners' Group submittal reports relative to the individual components. In addition, independent opinions were obtained from three leading diesel engine experts regarding these inspection requirements.

On the basis of its review, the staff has concluded that there is adequate justification for removing the present component-based licensing conditions. The staff's evaluation of the Owners' Group's submittal reports is in the attached safety evaluation (SE).

It is intended that the attached SE be referenced by affected licensees in proposals for changes to facility licenses to the extent specified and under the limitations delineated in the licensee submittals and the associated NRC evaluation. The evaluation defines the basis for the approval of the reports and is applicable to the eight Owners' Group licensees: Texas Utilities for Comanche Peak; Entergy Operations for Grand Gulf; Duke Power for Catawba; Carolina Power for Shearon Harris; Georgia Power for Vogtle; Cleveland Electric Illuminating for Perry; Grand Gulf Utilities for River Bend; and Tennessee Valley Authority for Bellefonte.

In accordance with procedures established in NUREG-0390, the TDI Owners' Group is requested to publish approved versions of the Owners Group reports as generic topical reports within three months of receipt of this staff approval. The accepted version should incorporate this approval letter and the enclosed evaluation between the title page and the abstract. The approved version shall include an -A (designating approved) following the report identification symbol.

The staff does not intend to repeat its review of the approved matters described in the approved generic topical reports when the reports appear as references in license applications except to assure that the material presented is applicable to the specific plant involved. The staff's approval applies only to the matters described in the reports.

Should the staff's criteria or regulations change so that the staff's conclusions as to the acceptability of the reports are invalidated, the Owners' Group and/or the licensees referencing the reports will be expected to revise and resubmit their respective documentation, or submit justification for the continued effective applicability of the reports without revisions of their respective documentation.

Sincerely,

James A. Norberg

James A. Norberg, Chief
Mechanical Engineering Branch
Division of Engineering
Office of Nuclear Reactor Regulation

Enclosure:
Safety Evaluation

UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555-0001

March 1, 1994

MEMORANDUM FOR: Ashok C. Thadani, Associate Director
for Inspection and Technical Assessment

FROM: M. Wayne Hodges, Acting Director
Division of Engineering

SUBJECT: SAFETY EVALUATION REPORT, PROPOSED REGULATORY CHANGES IN INSPECTION REQUIREMENTS FOR TRANSAMERICA DELAVAL, INC. (TDI), DIESEL GENERATORS AND WAIVER OF CRGR REVIEW

References:

(1) TDI Owners' Group submittal proposing removing of licensing conditions imposed by NUREG-1216, dated November 30, 1992.

(2) TDI Owners' Group Generic Licensing Submittal No. 2 for Emergency Diesel Generator Conditions of License for Utilities With Enterprise Engines, dated December 7, 1993.

(3) NUREG-1216, "Safety Evaluation Report Related to the Operability and Reliability of Emergency Diesel Generators Manufactured by Transamerica Delaval, Inc.," dated August 1986.

The Transamerica Delaval (TDI) diesel generators Owners' Group (Owners' Group) submitted proposals on November 30, 1992 (Reference 1) and December 7, 1993 (Reference 2), recommending removal of the licensing conditions imposed in 1986 as part of a technical resolution to address the so-called "TDI diesel generator issues" (namely, the concerns that were raised regarding the reliability of the TDI emergency diesel generators (EDGs) following the crankshaft failure at Shoreham in August 1983). The technical resolution involved implementation of Phase I and Phase II programs as identified in NUREG-1216 (Reference 3). The Phase I program focused on the resolution of known engine component problems that had potential generic implications, while the Phase II program focused on the design review of a large set of important engine components to ensure their adequacy from a manufacturing standpoint, as well as operational performance. At that time, the staff concluded that these components merit special emphasis in the area of load restrictions and/or maintenance and surveillance. The 16 major components which were identified included connecting rods, crankshafts, cylinder blocks, cylinder heads, piston skirts, and turbochargers. Engine load restrictions were addressed in the plant Technical Specifications, license conditions, engine operating procedures and operator training, as appropriate, for five of these components. The most critical periodic maintenance/surveillance actions for these components were incorporated as license conditions.

On the basis of substantial operational data and inspection results the Owners' Group provided information in its submittal reports of December 1992 and December 1993 (References 1 and 2) to demonstrate that the special concerns of NUREG-1216 (Reference 3) are no longer warranted. The Owners' Group contends that the TDI EDGs should be treated on a par with other EDGs within the nuclear industry and subjected to the same standard regulations, without the special requirements of NUREG-1216. In addition, the Owners' Group asserts that this action will improve availability of the engines for service, especially during outages, while maintaining current reliability levels.

The Mechanical Engineering Branch and its consultants at Pacific Northwest Laboratories (PNL) have completed a review of the operational data and inspection results contained in the Owners' Group submittal reports relative to the individual components. In addition, independent opinions were obtained from three leading diesel engine experts regarding these inspection requirements.

On the basis of the review, the staff's overall conclusion is that there is adequate and defendable justification for removing the present component-based licensing conditions. The staff's evaluation of the Owners' Group's submittal reports (References 1 and 2) is in the attached safety evaluation (SE). It is recommended that the transmittal of the SE to the TDI Owners' Group be approved without CRGR review for the following reasons:

(1) The proposed regulatory changes in the inspection, maintenance and surveillance requirements for the TDI diesel engines are consistent with the maintenance rule published on July 10, 1991, as 10 CFR 50.65.

(2) The proposed Owners' Group submittal refers only to requirements or staff positions previously applicable to the affected licensees.

(3) The proposed changes have adequate technical justification on the basis of a review of the current reliability data and inspection results of operating TDI engines throughout the last several years.

(4) These actions are consistent with current practice and do not represent a new staff position. Removal of license conditions would place the TDI engines on a par with other diesel engines in nuclear power plants.

(5) These actions are likely to result in improved availability of the TDI engines, while maintaining their current high reliability.

(6) Any licensee proposal to implement these changes is voluntary.

It is further recommended that the attached SE be approved for reference in license applications to the extent specified and under the limitations delineated in the licensee submittal reports and the associated NRC evaluation. The evaluation defines the basis for the approval of the reports. This generic SE would then be referenced by the eight Owners' Group licensees (Texas Utilities, Comanche Peak; Entergy Operations, Grand Gulf; Duke Power, Catawba; Carolina Power, Shearon Harris; Georgia Power, Vogtle; Cleveland Electric Illuminating, Perry; Grand Gulf Utilities, River Bend; and Tennessee Valley Authority, Bellefonte) to process operating license amendments on their plant dockets for removing the license conditions.

In accordance with procedures established in NUREG-0390, the TDI Owners' Group would be requested to publish approved versions of these submittal reports as generic topical reports within three months of receipt of the staff approval. The accepted version should incorporate this approval letter and the enclosed evaluation between the title page and the abstract. The approved version shall include an -A (designating approved) following the report identification symbol.

The staff does not intend to repeat its review of the approved matters described in the approved generic topical reports when the reports appear as references in license applications except to assure that the material presented is applicable to the specified plant involved. The staff's approval applies only to the matters described in the reports.

Should the staff's criteria or regulations change so that the staff's conclusions as to the acceptability of the reports are invalidated, the Owners' Group and/or the licensees referencing the reports will be expected to revise and resubmit their respective documentation, or submit justification for the continued effective applicability of the reports without revisions of their respective documentation. If you agree that a CRGR review is not necessary, please so indicate by signing below. Otherwise, we shall proceed with the preparation of an appropriate CRGR package.

Original signed by

M. Wayne Hodges, Acting Director
Division of Engineering

Enclosure:
As stated

ORIGINAL SIGNED
BY:

Approved: Ashok C. Thadani
CRGR review is not necessary

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EXECUTIVE SUMMARY

Concerns regarding the reliability of large-bore, medium-speed diesel generators manufactured by Transamerica Delaval, Inc. (TDI) for application at domestic nuclear plants were first prompted by a crankshaft failure at Shoreham Nuclear Power Station in August 1983.

In response to these problems, 11 (now 8) U.S. nuclear utility owners formed a TDI Diesel Generator Owners' Group (Owners' Group) to address operational and regulatory issues relative to diesel generator sets used for standby emergency power. The Owners' Group performed extensive design reviews of all key engine components and developed recommendations to be implemented by the individual owners concerning needed component replacements and modifications, component inspections to validate the "as-manufactured" and "as-assembled" quality of key engine components, engine testing, and an enhanced maintenance and surveillance program.

The staff evaluation of the Owners' Group program is documented in NUREG-1216. The staff concluded that implementation of the Owners' Group recommendations, with minor modifications, established the adequacy of the TDI diesel generators for nuclear standby service as required by General Design Criterion 17 of Appendix A to 10 CFR Part 50. The staff further concluded that these actions ensured that the design and manufacturing quality of the TDI engines is within the range normally assumed for diesel engines designed and manufactured in accordance with 10 CFR Part 50, Appendix B. Continued reliability and operability of the TDI engines for the life of the facilities was ensured by implementation of the maintenance/surveillance program described in NUREG-1216. The most critical periodic maintenance/surveillance actions for key components were incorporated as license conditions.

Since 1985, substantial operational data and inspection results have been accumulated by the TDI Owners' Group on the TDI engines. Although a few problems have been found, the engine components have generally performed satisfactorily and the reliability of the machines has been on an upward trend. In addition, many of the surveillance procedures that are in place have proved to be as effective as inspections for identifying potential problems.

On the basis of operational experience and inspection results, the Owners' Group provided information in its submittals of November 1992 and December 1993 to demonstrate that the special concerns of NUREG-1216 are no longer warranted. The Owners' Group contends that the TDI emergency diesel generators (EDGs) should be treated on a par with other EDGs within the nuclear industry and subjected to the same standard regulations, without the special requirements of NUREG-1216. In addition, the Owners' Group asserts that this action will improve availability of the engines for service, especially during outages, while maintaining current reliability levels.

The NRC staff, with assistance from its consultants at Pacific Northwest Laboratories (PNL), has completed a review of the operational experience and inspection results contained in the Owners' Group's submittals relative to the

individual components. In addition, independent opinions were obtained from three leading diesel engine experts regarding these inspection requirements.

On the basis of its review, the staff's overall conclusion is that there is adequate and defendable justification for removing the present component-based licensing conditions imposed on licensees based on recommendations in NUREG-1216 and that these TDI diesel engines can now be treated in the same regulatory manner as other EDGs within the nuclear industry.

SAFETY EVALUATION BY THE OFFICE OF NUCLEAR REACTOR REGULATION
OPERABILITY AND RELIABILITY REVIEW OF EMERGENCY DIESEL GENERATORS
MANUFACTURED BY TRANSAMERICA DELAVAL, INC.

I. INTRODUCTION

During the 1970s, many utilities ordered diesel generators from Transamerica Delaval, Inc. (TDI) for installation at nuclea[illegible]ts in the United States. The first of these engines to become operational in nuclear service were those at San Onofre Unit 1 in 1977. However, nuclear plant operating experience with TDI emergency diesel generators (EDGs) remained very limited until preoperational test programs were started at Shoreham and Grand Gulf Unit 1 in the early 1980s.

Concerns about the reliability of large-bore, medium-speed diesel generators manufactured by TDI for application at domestic nuclear plants were first prompted by a crankshaft failure at Shoreham in August 1983. However, a broad pattern of deficiencies in critical engine components subsequently became evident at Shoreham and at other nuclear and non-nuclear facilities employing TDI diesel generators. These deficiencies stemmed from inadequacies in design, manufacture, and quality assurance/quality control by TDI.

In response to these problems, 11 (now 8) U.S. nuclear utility owners[1] formed a TDI Diesel Generator Owners' Group to address operational and regulatory issues relative to diesel generator sets used for standby emergency power. On March 2, 1984, the Owners' Group submitted a proposed program ("TDI Owners' Group Program Plan") to the NRC that was intended to provide an in-depth assessment of the adequacy of the respective utilities' TDI engines to perform their safety-related function through a combination of design reviews, quality revalidations, engine tests, and component inspections.

The Owners' Group program addressed three major elements concerning the manufacture, inspection, and operation of TDI diesel engines:

(1) Phase I: Resolution of known generic engine component problems to serve as a basis for licensing plants during the period before completion of Phase II of the Owners' Group program.

(2) Phase II: A Design Review/Quality Revalidation (DR/QR), of a large set of important engine components to ensure that their design and manufacture, including specifications, quality control and quality assurance, and operational surveillance and maintenance, are adequate.

(3) Expanded engine tests and inspections as needed to support Phase I and II programs.

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[1] Carolina Power and Light Co. (Shearon Harris), Cleveland Electric Illuminating Co. (Perry), Duke Power Co. (Catawba), Georgia Power Co. (Vogtle), Gulf States Utilities (River Bend), Entergy Operations, Inc. (Grand Gulf Units 1 & 2), TVA (Bellefonte), Texas Utilities (Comanche Peak).

The NRC staff concluded in NUREG-1216, a safety evaluation report (SER) of August 1986 (Reference 1) that the Owners' Group program incorporated the essential elements needed to resolve the outstanding concerns relating to the reliability of the TDI EDGs for nuclear service. In keeping with recommendations from consultants at Pacific Northwest Laboratories (PNL) that certain components warrant special emphasis in terms of maintenance/surveillance (M/S) actions to ensure their adequate service, the staff incorporated key M/S actions for these components as license conditions.

The TDI Owners' Group submitted a proposal in December 1992 (Reference 2) along with supplementary information on December 7, 1993 (Reference 3) recommending removal of the licensing conditions imposed in 1986 as part of a technical resolution to address the so-called TDI diesel generator issues identified in NUREG-1216.

Since 1985, more than 9000 hours of operation have been logged collectively by the TDI engines. Although a few problems have been found, the engine components have generally performed satisfactorily, and the reliability of the machines has been on an upward trend. In addition, many of the surveillance procedures that are in place have proved to be as effective as inspections for identifying potential problems.

On the basis of operational experience and inspection results the Owners' Group has provided information in its submittal reports (References 2 and 3) to demonstrate that the special concerns of NUREG-1216 are no longer warranted. The Owners' Group contends that the TDI EDGs should be treated on a par with other EDGs within the nuclear industry and subjected to the same standard regulations, without the special requirements of NUREG-1216. In addition, the Owners' Group asserts that this action will improve availability of the engines for service, especially during outages, while maintaining current reliability levels.

The NRC staff, with assistance from its consultants at Pacific Northwest Laboratories (PNL) has completed a review of the operational experience and inspection results contained in the Owners' Group submittal reports relative to the individual components. In addition, independent assessments were obtained from three leading diesel engine experts regarding these inspection requirements.

On the basis of this review, the staff's overall conclusion is that there is adequate and defendable justification for removing the present component-based licensing conditions, and that the criteria and methodology proposed by the Owners' Group may be used to review all TDI components with inspection or safety concerns.

The staff developed criteria for judging the advisability of changing the regulatory basis for the TDI engines. All criteria were fulfilled as discussed in Section IV of this safety evaluation.

II. BACKGROUND

The three major elements of the technical resolution to address the TDI EDG issues as discussed in the SER dated August 1986 (NUREG-1216), are summarized below.

PHASE I PROGRAM

Phase I of the Owners' Group program focused on identifying and resolving significant engine component problems that had potential generic implications. Through an extensive review of TDI and other engine performance data in both nuclear and non-nuclear applications, the Owners' Group identified 16 components with such problems. These were:

- air start valve capscrews
- connecting rods
- connecting rod bearings
- crankshafts
- cylinder blocks
- cylinder heads
- cylinder head studs
- cylinder liners
- engine base and bearing caps
- engine-mounted electrical cables
- high-pressure fuel injection tubing
- jacket water pumps
- piston skirts
- push rods
- rocker arm capscrews
- turbochargers

The Owners' Group recommended that problems with these components be resolved before the TDI engines were placed into service to support full-power nuclear plant operations. To resolve the problems with these components, the Owners' Group contracted with Failure Analysis Associates (FaAA), Palo Alto, California, and Stone and Webster Engineering Corporation (SWEC), Boston, Massachusetts, to perform extensive design reviews. Each component was addressed by these consultants in one or more design review documents. Each design review report included, as appropriate, materials evaluations, load and stress analyses, fracture and fatigue analyses, and evaluations of required maintenance and surveillance. On the basis of these reviews, the Owners' Group arrived at conclusions regarding the basic adequacy of the 16 components with known problems, and recommended actions that should be taken by the engine owners.

Pacific Northwest Laboratories (PNL) was contracted by the NRC to assess the Owners' Group findings. PNL's assessment of the findings stemming from the Phase I program is documented in detail in PNL-5600 (Reference 4). On the basis of its assessment, PNL concluded that the Owners' Group had established a technical basis for the licensees to qualify all of the components with known problems (i.e., Phase I components) for nuclear service. PNL generally endorsed all of the Owners' Group recommendations pertaining to modifications, inspections, and maintenance/surveillance of Phase I components. However, PNL recommended some additional actions in these areas beyond those the Owners' Group had recommended. In addition, PNL and the staff concluded that five of the components warrant special emphasis in terms of needed load restrictions and/or maintenance/surveillance to ensure satisfactory service of these components.

In Revision 2 of the DR/QR report, the Owners' Group (Reference 5) proposed, and the staff accepted, that a complete engine overhaul be performed at approximately 10-year intervals. Namely, the DR/QR report specified that one engine/unit be disassembled and inspected at the refueling outage occurring before the 10-year interval and the second engine at the refueling outage occurring after the 10-year interval. For plants with three engines, the third engine would be disassembled and inspected during the second refueling outage after the 10-year interval. In addition, the Owners' Group later proposed that a one-time inspection be performed at about five years. The one-time 5-year inspection generally involved the same components as the 10-year overhaul inspection; however, only a sample of some types of components (typically 25%) were inspected.

PHASE II PROGRAM

Phase II of the Owners' Group program proceeded beyond known problem areas to systematically consider all components (approximately 150 to 170 component types per engine) important to the operability and reliability of the engines. Phase II was intended primarily to ensure that significant new problem areas do not develop in the future because of deficiencies in design or quality of manufacture. The Owners' Group performed the Phase II design reviews and, as was the case for Phase I, recommended needed component upgrades and modifications and component inspections to validate quality of manufacture and/or assembly. A major element of the Phase II program was the preparation of a comprehensive engine maintenance/surveillance (M/S) program to be implemented by the individual owners.

Design reviews performed by the Owners' Group for engine components at one plant were generally applicable to similar components at other plants. Similarly, quality revalidation inspections recommended by the Owners' Group for engine components at one plant were generally applicable to similar engine components at other plants, although the actual inspections were generally performed by the individual owners. The DR/QR reports for the Shoreham DSR-48 engines and Comanche Peak DSRV-16-4 engines generally constituted the lead-engine reviews. The reports were extensively referenced in DR/QR reports prepared for other plants.

The staff's contractor, PNL, performed a detailed audit review of the DR/QR reports for the Shoreham DSR-48 engines and for the Comanche Peak DSRV-16-4 engines. These PNL reviews are documented in PNL Reports PNL-5336 (Reference 6) and PNL-5444 (Reference 7), respectively. PNL found that the DR/QR efforts fully met the intent of the Owners' Group program plan, which was to establish "reasonable assurance of the ability of the TDI engines to provide reliable backup power supplies for nuclear power plant service."

The staff concluded in its SER dated August 1986, (Reference 1) that implementation of the Owners' Group recommendations in the Phase II reports will be effective in improving and ensuring the design adequacy and quality of the engine components and, hence, the reliability and operability of the TDI engines at the various Owners' Group nuclear plants.

MAINTENANCE/SURVEILLANCE PROGRAM

The staff viewed the implementation of a comprehensive M/S plan to be a key element of the overall effort to establish and maintain TDI diesel engine reliability and operability.

As a result of its generic Phase I and Phase II component reviews, the Owners' Group developed an M/S plan applicable to each member utility's engines. The plan for each plant, which supplemented the existing TDI Instruction Manual, was developed by the Owners' Group from (1) its detailed review of each component's service history; (2) TDI Service Information Memoranda (SIMs) and correspondence on specific components, and (3) the Owners' Group technical reviews done during the Phase II DR/QR reviews. The Owners' Group recommendations are documented in Appendix II of the DR/QR report for each plant.

The staff concluded in NUREG-1216 that the following elements constituted an acceptable program:

(1) the recommendations concerning operation, testing, inspection, maintenance, adjustment, overhaul, and repair of the engine as incorporated in the TDI Instruction Manual, SIMs and TDI correspondence on specific M/S issues

(2) the M/S recommendations developed by the Owners' Group in Appendix II, Revision 2, of the DR/QR reports

(3) additional items required by the staff in individual plant license conditions

The staff also specified in NUREG-1216 that each plant owner commit to an acceptable M/S program, as identified above, before the staff issued final plant-specific SERs addressing the final resolution of the TDI engine issues.

Typically, detailed steps of preventive M/S programs for such important safety-related systems as diesel generators are not incorporated as part of the plant license or the plant technical specifications. Accordingly, changes to these programs are not normally subject to NRC staff review and approval. In keeping with the PNL recommendations as endorsed by the staff in NUREG-1216, that certain components warrant special emphasis in terms of M/S actions to ensure their adequate service, the staff included key M/S actions for these components as licenses conditions.

III. DISCUSSION

In its submittal reports of November 30, 1992, and December 7, 1993 (References 2 and 3), the Owners' Group is proposing that the current prescriptive M/S requirements, including a specified overhaul frequency, be removed as a license condition and the licensees be allowed to determine when an overhaul is required and how it will be conducted. The Owners' Group is presently developing a generic diesel management program in conjunction with the manufacturer which incorporates predictive maintenance techniques based on a combination of inspections, monitoring, and trending. The Owners' Group proposes to use this generic diesel management program in lieu of the current maintenance/surveillance requirements.

On the basis of the substantial operational experience of the TDI EDGs accumulated since 1985 and the inspection results of the EDG components, the Owners' Group has provided information in its submittal reports of November 30, 1992, and December 7, 1993 (References 2 and 3) to demonstrate that the special concerns of NUREG-1216 are no longer warranted. The Owners' Group has recommended removing the license conditions related to EDG component inspections involving teardowns and surveillance requirements.

The Owners' Group has analyzed the need for engine overhauls in accordance with the current DR/QR requirements. Their analysis and conclusions are based on an understanding of the historical concerns for each component affected by the overhaul and the results of extensive inspections performed by the licensees who make up the TDI Owners' Group. The information in its submittal reports includes component description, component identification number per the DR/QR Appendix II, "Preventive Maintenance (PM) Task Description," the manufacturer's replacement/overhaul recommendations, the number of engine hours run between inspections or cumulative engine hours, number of engine starts, inspection findings, and the percentage of all components in service covered by the inspections. The results of the inspections compiled by the Owners' Group in its submittal reports (References 2 and 3) indicate that most teardowns have shown little or no wear on internal engine components. However, with continuing operation, it is possible that problems could occur with specific components which could require inspection or overhaul of affected components. The Owners' Group is proposing that such actions be determined on a case-by-case basis, and that inspections or overhauls be performed so that engine reliability and availability are maximized. The Owners' Group contends that the primary purpose of EDG 10-year teardown inspections is to document the condition of the specific components, not to replace components, since most components being inspected show little or no wear. However, as a matter of good maintenance practice, these components are generally replaced after a teardown inspection, regardless of condition. These teardowns can result in reassembly errors or entry of foreign materials resulting in increased wear or decreased engine reliability.

The Owners' Group believes that an overhaul will be needed during the life of these engines as they are currently operated. However, due to the limited number of run hours and the availability of periods to perform major teardowns the licensees need the flexibility to determine when an overhaul is required and how an overhaul is conducted.

The Owners' Group contends that some of the early concerns with EDG components were caused by the deleterious effects of the fast starts and loading of EDGs in nuclear service. The Owners' Group notes that the life expectancy of most engine components in commercial service, which are not subject to fast starts, is far greater than the estimated life of EDG components in nuclear service based on early data.

All licensees have the authority to delete fast-start and loading requirements on the basis of Generic Letter (GL) 84-15, and are committed to doing so.

However, some licensees have not taken this step for a number of reasons. First, many engines have control systems which will not allow a slow start. The necessary changes in such control systems are currently being implemented. Second, some of the TDI licensees want to consolidate all changes for a particular technical specification (TS) to lessen the impact on the licensee and the NRC workload resulting from a TS change request. The staff is currently preparing a GL addressing the requirements for accelerated testing of emergency diesels. Most licensees are waiting for this GL to be issued before requesting a change to their TSs which would include a request for the deletion of the fast starts. Once the slow start option is implemented and accelerated testing is eliminated, engines at nuclear plants will be operated similarly to those in commercial service, and the expected life of components in engines at nuclear plants should compare favorably with commercial engine components. The data from engines in nuclear service which have implemented the slow-start option supports this contention. Since the manufacturer's recommendations for commercial operation of TDI/EDG components prior to overhaul indicate that there are substantial safety margins available, appropriate changes can be made in M/S requirements based on realistic estimates of component life expectancy, and flexibility can be achieved in the frequency of performing teardown inspections.

The Owners' Group, in its submittal reports, has also discussed the need for flexibility in scheduling teardown inspections from the standpoint of shutdown risk management (SRM). According to the Owners' Group, the "available windows" of outage time of sufficient length to allow engine teardowns and/or overhauls are being shortened because of SRM requirements. The "available window" during which a diesel can be removed from service for maintenance depends on a number of factors, including plant design, availability of alternate power sources, fuel handling schemes, and other operational, maintenance, or inspection requirements. These factors cause the "available window" to vary from outage to outage. Typically, the "available window" is between 10 and 21 days; however, SRM programs have compressed this "window" by as much as 20%. As a result of this shortening of "available windows," all plants need maximum flexibility in scheduling EDG maintenance activities (i.e., schedule major diesel work during times when longer "windows" are available without impacting overall outage length). Time-directed teardowns/overhauls do not allow this flexibility. The Owners' Group is proposing a generic diesel management program which combines predictive maintenance, surveillance, and inspection. The Owners' Group contends that with this program, considerable flexibility can be achieved in the frequency of performing teardowns and/or overhauls without sacrificing engine reliability.

Typical components that are inspected or replaced or both during an engine overhaul are turbochargers, main bearing caps/studs, cylinder blocks, connecting rods/bearings/bushings, cylinder heads, push rods, lower cylinder liner seals, base assemblies, crank shafts, cylinder liners, pistons/rings, fuel injection tubing, and rocker arm capscrews/drive studs. Problems with these components resulting from the intrusive inspections could certainly limit or preclude the engine's acceptable power output. Disassembly of these components can result in the accidental introduction of dirt and other foreign materials that may harm the engine. In addition, these components are assembled with a precision fit of the mating surfaces. Disturbance of these fits can cause different wear patterns to develop, resulting in accelerated wear and a shortened component life.

The operational data and the inspection results for the key components are reviewed in Appendix A. The Owners' Group assesses that these components can be expected to operate for the 40-year life of the plant without failure. The Owners' Group diesel management program contains a comprehensive list of engine and auxiliary system parameters to be monitored and trended. This diesel management program offers guidance on the monitoring frequencies, normal operating ranges for the various parameters, alert levels, and corrective actions. The licensees will monitor and trend data collected during engine runs and standby conditions to determine the overall operational readiness of the engine. Should the monitored data indicate that a potential problem exists, additional tests and evaluations would be conducted which could result in teardown inspections or component replacement or both. It is the intent of the Owners' Group diesel management program to detect problems and correct them before they affect the ability of the engine to perform its design function.

RECOMMENDATIONS OF THE EDG EXPERTS

The staff solicited independent assessments from three EDG experts of the operational experience and inspection results contained in the Owners' Group submittals (References 2 and 3). The experts who participated in this review are Paul Louzecki, Adam Henriksen, and B. J. Kirkwood. Together, they represent well over 100 years of large diesel engine experience. They were of the opinion that there were no adverse trends in the data obtained from the inspection results, and that the Owners' Group submittals represented adequate understanding of inspection and maintenance needs. On this basis, they thought that consideration of realignment of the TDI engine regulatory requirements to those considered normal for such equipment was a positive action. The recommendations offered by the EDG experts and the staff's evaluation of specific recommendations is summarized in Appendix B of this report.

IV. EVALUATION

The staff, with assistance from its consultants, developed specific criteria to guide the review process and evaluate the adequacy of the rationale for the removal of component-based license conditions. The criteria consisted of the following five elements:

- Adequate justification should exist for changing applicable license conditions for the TDI engines.

- Since the original regulatory issue was improvement of TDI engine reliability, the current TDI engine reliability should be equal to or better than the industry average.

- Because specific surveillances/inspections were imposed by regulation to ensure that acceptable engine conditions were being maintained, the inspection results should not identify unacceptable findings.

- The Owners' Group should have an alternative diesel management program with elements that are judged by the regulatory staff to be reasonably and equally effective compared to current license requirements in maintaining diesel reliability.

- The underlying source or technical basis for the proposed regulatory change should be justified by authorities and expertise equal to that which determined the current regulatory requirements.

As discussed in the following paragraphs, all five criteria have been satisfied. The current TDI engine reliability was found to be equal to or better than the industry average. In the period between January 1990 and December 1992, the median reliability of TDI diesels was found to be 0.9906. This is about 1% better than the nuclear industry average, and well above NRC's highest goal of 0.975.

Specific surveillances/inspections were imposed by NRC regulations to ensure that acceptable TDI engine conditions were being maintained. A review of the operational database and the inspection results for the key components, as discussed in Appendix A, show no unacceptable findings. In fact, most inspections did not uncover any signs of wear or degradation that need to be addressed.

NRC-sponsored research (Reference 8) has indicated the potentially negative consequences of intrusive inspections on components and engine reliability as a result of current practices. In a study of failures related to aging, a failure curve, sometimes called the "bathtub" curve, correlates the change in failure rate with age. The beginning segment of the curve represents a "wear-in" portion, with a higher failure rate associated with many pieces of new equipment. Once the machinery is broken in, the failure rate is at its lowest and remains constant for a period of time. As the machinery wears and reaches the end of its lifetime, the failure rate increases. The challenge is to determine the time scale for these regions for each piece of equipment. On the basis of these studies, it is generally believed that the diesel engine's reliability is considerably lower during the "wear-in" period, and some engines may be on the lower end of the acceptable range of reliability, during the "wear-in" period of operation.

Some of the early concerns with EDG components were due to the deleterious effects of fast start and loading of EDGs in nuclear service. Component life expectancy in commercial TDI engines which are not subject to fast starts is far greater than life expectancy for TDI engine components in nuclear service. Although the fast-start requirements have been relaxed on the basis of GL 84-15, not all licensees have implemented the changes in the EDG control system to permit slow starts. All members of the Owners' Group are committed to implementing these changes in the near future. The staff is also addressing the issues related to accelerated testing in a generic letter to be issued shortly. Once the slow start option has been implemented and accelerated testing has been eliminated, nuclear service engine operation will more closely match that of engines in commercial service and the expected component life for TDI engines in nuclear service should compare favorably with commercial engine component life. The data from engines in nuclear service which have implemented the slow-start option supports this contention. A review of the manufacturer's recommendations for commercial operation of TDI/EDG components before overhaul indicates that there are substantial safety margins available for most components in nuclear service. The staff concurs with the Owners' Group recommendation that by combining predictive maintenance, surveillance, and inspections, as in the proposed generic diesel management program, considerable flexibility can be achieved in the frequency of performing engine teardowns and/or overhauls without sacrificing engine reliability.

The Owners' Group contends that the "available windows" of outage time of sufficient length to allow engine teardowns and/or overhauls are being shortened due to SRM requirements. As a result of this shortening of available windows, all plants need maximum flexibility in scheduling EDG maintenance activities. The adoption of a predictive maintenance program for EDGs as proposed, in lieu of the current time-directed teardown/overhaul requirements would give the licensee this flexibility without jeopardizing engine reliability.

The Owners' Group has requested the removal of inspection requirements from the license conditions. The Owners' Group proposes to continue appropriate inspections; however, scope, inspection schedules, and especially the amount of intrusive inspections involving disassembly would be changed to maximize EDG availability and reliability. Inspections would be planned to respond to monitoring and trending results and where other maintenance activities make the component accessible, such as in response to failures of nearby components or where monitoring is indicating an end of component life conditions. The Owners' Group will continue appropriate inspections, especially those not involving engine disassembly. Inspections will be defined and included as part of a well-managed engine program currently under preparation. Elements of correct engine management have been reported previously to the NRC and industry (References 8 and 9). Key features of an EDG management program, acceptable to the staff (see Appendix C of this safety evaluation) have been discussed and provided to the Owners' Group. The Owners' Group agrees that each member would adopt the group's proposed generic management program, resolution, or mitigating actions, and that all actions are intended to be acceptable to the manufacturer.

Finally, the underlying source or technical basis for the proposed regulatory change is equal in expertise to that which was responsible for recommending the current regulatory requirements. The TDI Owners' Group, with support from the manufacturer, was instrumental in preparing the technical basis for the original regulatory conditions in NUREG-1216.

V. OVERALL CONCLUSIONS

The staff, with assistance from its consultants and recognized diesel engine experts, concluded that the regulatory requirements on TDI engines may be reconsidered at this time. This conclusion is based on a review of the current reliability data of the TDI engines, the Owners' Group inspections of the last several years, and the opinion of experts who have experience in the design and operation of large diesel engines. The staff believes that the TDI Owners' Group, like any other owners group, must address the unique maintenance needs for its specific engine to keep the reliability factor acceptable. With a current median reliability of 0.9906, the TDI Owners' Group, and its individual owners, seem to fully understand the maintenance needs of this engine. The staff further believes that there is sufficient information in the Owners' Group submittal reports to conclude that TDI engine operation at authorized loads is acceptable under normal NRC regulatory oversight procedures for EDGs. The staff and its consultants, in their review of the TDI submittal reports and the operational database, did not uncover any new concerns or issues. Individual reports from recognized experts endorse many of the TDI engine management practices, inspections, or precautions. The Owners' Group intends to incorporate most of the inspections and precautions from the current M/S requirements in its generic diesel management program and appropriately supplement these inspections with alternate condition monitoring procedures. All members of the Owners' Group are committed to implement this diesel management program.

The key features of a maintenance program which the staff finds acceptable are delineated in Appendix C of this safety evaluation. The staff has reviewed the preliminary version of the diesel management program, which the Owners' Group is proposing in lieu of the current M/S requirements. The staff finds the principal elements of this program acceptable. The proposed maintenance program is in conformance with the requirements in Regulatory Guide 1.160, "Monitoring the Effectiveness of Maintenance at Nuclear Power Plants," dated June 1993, which endorses NUMARC 93-01 dated May 1993, "Industry Guide for Monitoring the Effectiveness of Maintenance at Nuclear Power Plants."

Accordingly, the staff has concluded that the license conditions related to the periodic M/S program (see Appendix D of this safety evaluation) for certain components (see Appendix E of this safety evaluation) which were imposed on the licensees based on the recommendations in NUREG-1216, be removed at this time. Therefore, the detailed steps of the preventive M/S programs will not be subject to NRC staff review and approval. However, the staff believes that future revisions of the M/S program would be subject to the provisions of 10 CFR 50.59 (Code of Federal Regulations) in view of the importance of the M/S program in ensuring the operability and reliability of the engines. The staff will require that the owners of each plant commit to the current M/S program in the interim period preceding the implementation of the generic diesel management program currently under development in association and agreement with the manufacturer. The transition from the current M/S program to the generic diesel management program could be accomplished under the provisions of 10 CFR 50.59. The TS requirements of subjecting the diesel to an inspection in accordance with procedures prepared in conjunction with its manufacturer's recommendations for the class of standby service would continue to remain in effect, similar to the TS requirements on other EDG manufacturers.

VI. REFERENCES

(1) NUREG-1216, "Safety Evaluation Report Related to the Operability and Reliability of Emergency Diesel Generators Manufactured by Transamerica Delaval, Inc.," dated August 1986.

(2) TDI Owners' Group submittal proposing removal of licensing conditions imposed by NUREG-1216, dated November 30, 1993.

(3) TDI Owners' Group Generic Licensing Submittal No. 2 for Emergency Diesel Generator Conditions of License for Utilities with Enterprise Engines, dated December 7, 1993.

(4) PNL-5600, "Review of Resolution of Known Problems in Engine Components for Transamerica Delaval Inc. Emergency Diesel Generators," December 1985.

(5) George J. B., Chairman, TDI Owners' Group, letter to H. R. Denton, NRC, "Revision 2 of Final DR/QR Reports for TDI Diesel Generators," May 1, 1986.

(6) PNL-5336, "Review of Design Review and Quality Revalidation Report for the Transamerica Delaval Diesel Generators at Shoreham Nuclear Power Station Unit 1," October 1985.

(7) PNL-5444, "Review of Design Review and Quality Revalidation Report for the Transamerica Delaval Diesel Generators at Comanche Peak Steam Electric Station Unit 1," October 1985.

(8) NUREG/CR-5057, K. R. Hoopingarner and F. R. Zaloudek, "Aging Mitigation and Improved Programs for Nuclear Service Diesel Generators," Pacific Northwest Laboratory, PNL-6397, December 1989.

(9) NUREG/CR-5078, E. V. Lofgren, W. Henderson, D. Burghardt, L. Kripps, B. Rothleder, "A Reliability Program for Emergency Diesel Generators at Nuclear Power Plants," Science Applications International Corporation, December 1988.

APPENDIX A

SUMMARY OF OPERATIONAL EXPERIENCE AND INSPECTION RESULTS OF EMERGENCY DIESEL GENERATOR (EDG) COMPONENTS

The operational data and inspection results of key EDG components compiled by the TDI Owners' Group are summarized below.

Base Assemblies

In the original TDI Owners' Group review of the DR/QR report, it was determined that adequate factors of safety exist in the design of this component. Problems with this component were reported in non-nuclear service engines and were the result of inadequate bolt preload and, in one case, marginal strength due to an inferior quality casting. Subsequent testing and/or inspections have been made by the owners to confirm that castings in service are of acceptable quality. In addition, steps have been taken to ensure adequate bolt preload.

The Owners' Group submittal reports cited 52 inspections representing 90% of the total population of base assemblies. The total (average) hours logged in EDG operation is 900 and the average number of starts is 400. No problems were noted from the inspections.

These inspection results, coupled with previous Owners' Group analyses, show that the base has a life expectancy of more than 40 years. The staff, and its consultant at PNL, concluded in Reference 4, Section 4.12.3.2.1, that the components of the base assembly have sufficient strength to operate at full load, provided the base casting and bolting components meet their nominal material and dimensional specifications, and the bolt torque specifications are maintained. As noted above, sufficient inspections/tests have been completed to indicate that the casting and bolt specifications are adequate. On this basis, the Owners' Group concludes that eliminating time-based inspections of this component is appropriate. Similar experience with non-nuclear engines shows a life expectancy in excess of 40 years. The Owners' Group diesel management program will have provisions for monitoring the condition of the base assembly. Visual inspections during normal operation, as well as during startups and warmups, would indicate if the base assembly is properly anchored and torqued. In addition, a change in the vibration measurements would indicate potential problems with this component.

Main Bearing Caps/Studs

Concerns about the main bearing caps/studs were initially raised by the cracks observed in the bearing cap stud holes at the Shoreham plant in 1984. The cause of this problem was related to the stud removal method (Reference 4, Section 4.12.3.2.1). After corrective actions were implemented, cracks have not been observed in subsequent inspections.

The Owners' Group submittal reports cited 108 inspections of caps, studs, and nuts, which is 50% of the components currently in service. The total (average) hours logged in EDG operation is 1,000 and the average number of starts is 490. All inspections were conducted with at least 600 hours of operation. A number of inspections have been performed on engines with more than 2,000 hours of operation. No problems were noted during these inspections. On the basis of the high safety factors and favorable inspection results, the Owners' Group concluded that these components should not require overhaul for the 40-year life of the plant. Manufacturer information indicates that this component in non-nuclear engines has a life expectancy in excess of 40 years.

Early indication of main bearing caps/stud problems will be obtained by monitoring several parameters which include hot and cold crankshaft web deflections and amount of wear particles in engine oil.

DSR-48 Series Engines--Crankshafts

The only utility with the DSR-48 engine is the River Bend station. The EDG engines at River Bend have crankshafts with the same dimensions as the replacement shafts at Shoreham. However, because of differences in the generators and flywheels between the two installations, resulting crankshaft torsional stresses are different. A complete analysis of the Shoreham replacement crankshaft has shown that it has a fatigue life in excess of 40 years under nuclear service operating conditions. Comparison of the crankshaft torsional stresses in the Shoreham engines at an operational load of 3300 kW to the torsional stresses in the River Bend engines at an operational load of 3130 kW shows that the torsional stresses are equivalent at these respective loads. Therefore, the River Bend engines have been derated for nuclear service. The Owners' Group and PNL analyses indicate a projected fatigue life in excess of 40 years for the River Bend crankshafts at loads under 3130 kW (Reference 4, Section 4.6.7.2).

A significant number of fillets, oil holes and journals have been inspected on the DSR engines. The inspections were conducted with over 700 hours in EDG operation and 270 starts with no problems. The River Bend engines have been derated and are operated at less than 3130 kW at all times. On the basis of previous analyses conducted by the Owners' Group and PNL (Reference 4, Section 4.6.7.2), engine operational power limits and the inspection results, the Owners' Group believes that overhaul of the River Bend crankshafts should not be required for the 40-year life of the engine. Manufacturer information on non-nuclear engines indicate a life expectancy in excess of 40 years for the crankshaft.

The Owners' Group diesel management program will have provisions for monitoring several parameters which would give an early indication of potential problems and the need to perform teardown inspections. These parameters include hot and cold crankshaft web deflections, amount of wear particles in engine oil and vibration amplitudes.

DSRV-16 Crankshaft

The DSRV-16 crankshafts at each site have been independently evaluated to determine the impact of torsional stresses on the life of the component. No problems have been identified with this component. The Owners' Group analyses

(Reference 4, Section 4.7) indicates a fatigue life in excess of 40 years for these components.

Approximately 25% of the oil holes, fillets and journals have been inspected on the DSRV-16 crankshafts. The minimum number of hours of engine operation at inspection was more than 700, while several inspections were done on engines with more than 2,000 hours of operation. More than 70% of the engines are already operating in a region of the fatigue curve, where imposition of additional stress cycles is no longer a concern. Based on operating power limits, calculated fatigue life in excess of 40 years, and the positive inspections conducted with significant operating hours, the Owner Group concludes that this component would not be expected to require an overhaul within the 40-year operating life of the engine.

As stated earlier, the Owner Group diesel management program will require monitoring and trending of several parameters which would give an early warning and need for a teardown inspection of this component.

Cylinder Blocks

A thorough design review of this component was completed during the initial DR/QR review. This review indicated that some castings fabricated during the period when the Owners' Group engines were manufactured could contain Widmanstaetten graphite. Widmanstaetten graphite is an inclusion that weakens the grey iron casting. It was shown that blocks containing this material have a greater potential for developing cracks. However, it was also shown that should these cracks develop for any reason, they would not affect the block's ability to perform its intended design function. Analyses indicated that cracks would tend to arrest without impacting the block performance. However, if the worst case scenario of crack propagation is assumed, it was shown that the water flow would be to the block exterior. This degradation would not impact engine performance and would be readily detectable. A cumulative fatigue usage index formula was developed and an inspection frequency was established based on that usage factor. The Owners' Group and PNL concluded in the earlier reviews that "If cumulative results of these inspections over several power plant fuel cycles show that one or more of the inspections reveal nothing of significance, the scope and frequency of the inspections could be reconsidered" (Reference 4, Section 4.9.5.2).

All engines currently in nuclear service have had block top inspections performed with 600 hours or more of EDG operation. No block cracking has been identified. On the basis of design analyses of engine blocks which indicate that cracking will not impact EDG performance and inspection results of engines with significant accumulated operating hours, the Owners' Group expects that this component will operate for the life of the plant without overhaul. Non-nuclear experience with this component indicates a life expectancy in excess of 40 years. The Owners' Group diesel management program has provisions to monitor potential crack growth via nonintrusive techniques, such as tracking the frequency of jacket water and lube oil makeups, and looking for signs of contaminants in lube oil and jacket water.

DSRV-16 Articulated Connecting Rods

Problems have been found on DSRV articulated connecting rods with 1-1/2-in. bolts. These problems were discovered before the DSRV engines were used in nuclear service and during the early startup periods of the nuclear engines. The root cause of these problems was determined to be inadequate connecting rod bolt preload. To address this concern, the Owners' Group utilize assembly procedures which accurately verify connecting rod preload (stretch or torque measurement techniques). These preload measurement methodologies have been in use during past inspections. Since the implementation of these methodologies, no connecting rod problems have been reported.

TDI engines at one plant are furnished with 1-7/8-in. bolts in the connecting rods. Analyses indicate that bolt stresses are satisfactory as long as the bolts are properly torqued and the engine operating load is limited so that connecting rod stresses remain below the fatigue initiation curve. Operating load for this engine has been limited to ensure that this condition is met. Preload measurement is also used to ensure proper bolt loading. There are 144 pairs of articulated connecting rods in service in 18 engines.

Extensive inspections of the connecting rods have been conducted without uncovering any problems. Several engines had logged more than 2,000 hours of EDG operation at the time of the inspections. All licensees have implemented the use of preload measurement techniques. For the 1-1/2-in. bolts, adequate margin against failure has been shown to exist at engine design load. The one utility with engines using the 1-7/8-in. bolts has instituted engine operating load limits to ensure that fatigue failure is precluded. On the basis of the design margins, the use of preload measurements, an operating load limit for engines with 1-7/8-in. bolts and the inspection results, the Owners' Group expects this component to last in excess of 40 years without overhaul. However, the Owners' Group will verify preload whenever a connecting rod assembly is replaced or overhauled.

Non-nuclear users typically run engines 50,000 hours before replacing of this component and 35,000 hours before replacing the rod eye bushing. The Owners' Group diesel management program will have provisions to monitor this component through several means. Oil analysis will be performed to detect the presence of wear metals indicating abnormal bearing/bushing wear. Engine analyzers would be utilized to gain information about abnormal functions of cylinder power components including connecting rods.

Pistons/Rings

All nuclear users have installed the AE model piston skirts. These piston skirts have previously been qualified at the rated engine load and have been validated for their fatigue life on 13 of the 20 engines in service. PNL concluded in an earlier analysis (Reference 4, Section 4.16.3) that the AE model piston skirts are adequate for service at their rated load and overload conditions. There are currently 304 pistons in service in 20 engines and 91 inspections have been performed. The average run time of EDGs preceding inspections is 800 hours and the average number of starts is 500. The inspections revealed no problems. This represents 25% of the total population of pistons inspected. Pistons and rings have been one of the more reliable components in nuclear service. Some inspections have been conducted with more than 2,000 hours of operation. Inspections have revealed no stress- or wear-related concerns. On the basis of the number of hours logged in service, the favorable inspection results, and the design margin, the Owners' Group expects that the AE piston skirts and rings would last the 40-year life of the plant. Non-nuclear users typically run engines 60,000 hours prior to replacing pistons and 20,000 hours prior to replacing rings.

The Owners' Group diesel management program will have requirements to monitor several parameters that would detect the need for an overhaul, or for intrusive inspections if problems develop. These parameters include engine compression, firing pressures, and crankcase pressure.

Cylinder Heads

Cylinder heads for the DSR-48 series and DSRV-16 series engines are similar in design and are addressed as one component. Cylinder heads are grouped in three categories, Group I, II, or III. These groupings identify three distinct periods of design and design/fabrication control. These periods are marked by changes in the casting and fabrication of the heads and in the weld techniques used to repair the heads. Some of all three groups of heads remain in nuclear service today. PNL, in an earlier review, endorsed the Owners' Group findings and concluded that all groups of heads are adequate for their intended service (Reference 4, Section 4.10.3.3). Any cracks which develop would not be detrimental to engine performance. Water flow from a crack would be to the exterior of the engine, this flow would be readily detected and would allow the head to be repaired or replaced. As an added precaution against cylinder head cracking, air rolling of the engine with the indicator ports open is used at all sites to check for potential water leakage. Cylinder head cracking or water inleakage has been observed. An earlier 10 CFR Part 21 notification regarding leakage through a small thinned area has been evaluated by the staff and a program to address the problem has been implemented. This is documented in the response to the notification. There are currently 304 heads in nuclear service on 20 engines.

This component has been extensively inspected. The average operating hours on the cylinder heads is 1,000 and some heads have operated for more than 2,000 hours. No cylinder head cracking has been identified, which has caused a loss of engine performance. On the basis of the large number of operating hours, and the favorable inspection results, the Owners' Group expects this component to last the 40-year plant life without needing overhaul. Non-nuclear users typically run their engines 35,000 hours before overhauling this type of component.

The Owners' Group diesel management program will require monitoring and trending of several parameters which would detect problems with this component and the need for further inspections. These include cylinder exhaust temperatures, compression, and firing pressures. In addition, a number of visual inspections and tests would be performed periodically to detect problems with this component.

Fuel Injection Tubing

A 10 CFR Part 21 notification was issued by the vendor on July 10, 1983, alerting TDI diesel engine owners and the NRC to a condition that may cause the tubing to fail. This condition results from a draw seam that acts as a stress riser on the inner surface of the tube. The draw seam is induced during the drawing phase of the manufacturing and generally will extend over most of the length of the tube and is readily detectable. On the basis of an analysis of the structural strength of the tubing, it was determined that the tubing is acceptable as long as no preexisting flaws greater than 0.0054-in. in depth existed. This prompted the recommendation to test the tubing for presence of cracks or to install shrouded tubing which has double walls. The reasons for the concern are the potential for fire resulting from a broken tube or a high-pressure fuel oil leak.

On the basis of the service record of this component and the ease of inspecting for leaks during operation, this component need not be overhauled. However, life of each fitting and tube assembly cannot be assured over the 40-year life because of vibratory loads or wear and tear during maintenance. The Owners' Group is proposing periodic inspections to monitor tubing for leakage and repair as required. Commercial engine life for this component is approximately 35,000 hours.

Push Rods

Major problems with this component resulted from a previous TDI design which is no longer in use at nuclear facilities. Nuclear engines currently employ the friction-welded design. The performance of this design in nuclear service has been excellent. An Owners' Group evaluation indicates that there are acceptable factors of safety against failure due to fatigue or buckling for this component.

No problems have been identified since replacements were made with push rods incorporating the friction-welded design. On the basis of the design margins for this component, significant number of operating hours, and number of inspections, the Owners' Group expects this component to achieve the 40-year life without failure. Non-nuclear users typically run engines for 100,000 hours before replacing them. The Owners' Group diesel management program will require monitoring and trending of several parameters which would detect potential problems with this component and the need for further inspections.

Rocker Arm Capscrews/Drive Studs

During the initial DR/QR process, the Owners' Group determined that capscrew failures had occurred on an isolated basis. Failures had been caused by insufficient preload on the capscrews. The Owners' Group performed a detailed design review of the component to ensure that the appropriate stresses are within allowable limits. The Owners' Group and PNL concluded in Reference 4, Section 4.18.4.3, that "If the rocker arm capscrews are installed with the proper preload, they should not require any M/S until they are removed for other reasons."

The Owners emphasized eliminating the cause of the original capscrew failures. Capscrew installation procedures have been modified to ensure proper preload, which was identified as a cause for the early failures. On the basis of the inspection results and the adequate design margins identified, the Owners' Group does not expect these components to need replacement during the 40-year life of the plant. These components are accessible with the subcovers removed and can be visually inspected. The Owners' Group diesel management program will have requirements for periodic inspections.

Lower Liner Seals

The lower liner seals consist of elastomeric O-rings that form a seal between the liner and block assembly. This seal prevents engine cooling water or jacket water from mixing with lube oil. The seals are made of Viton, an elastomer that has an excellent record of service in such applications. There are three seals for each cylinder which provide multiple barriers in the unlikely event that one of the seals fails.

Currently, these seals are replaced on a time-dependent basis. Monitoring the oil and jacket water levels gives an alternate means for determining if these seals need to be replaced. A significant number of inspections of these seals have revealed no degradation. In addition, the multiple seal design gives added protection against seal failure which could impact engine performance. On the basis of the failure monitoring capability, the multiple seal design feature and favorable inspection results, the Owners' Group does not expect the lower liner seals to need replacement during the 40-year life of the plant unless the liner is removed for other reasons. This conclusion is also supported by the vendor's non-nuclear engine experience. The Owners' Group diesel management program will have provisions for monitoring the condition of this component.

Turbochargers

Problems associated with turbochargers have been related to bearing wear and damage to the stationary vanes due to vibration. To address bearing wear issues, the licensees have installed drip and full-flow prelubrication systems. These systems lubricate the turbocharger bearings during standby conditions prior to planned starts. In addition, the Owners' Group oil sampling program is a means of detecting metallic particles that would be an early indication of bearing wear. Finally, inspection results indicate (Table 1, Component MP-022/023, Reference 3) that significant bearing wear has not affected turbocharger performance.

Four TDI engines have experienced failure of a stationary vane at the turbocharger inlet. This condition was found on two of these engines as early as 1984 in the original DR/QR review. The Owners' Group, and its consultants. Failure Analysis Associates, determined the failures to be caused by high-cycle fatigue. This fatigue results from the pulsations created by the engine exhaust during operation as the gases pass through the turbocharger inlet area to drive the rotating vane group. These failures, in all cases, resulted in the stationary vane being reduced to small pieces and passing through the rotating vanes of the turbocharger with no impact on the turbocharger or engine performance. Subsequent inspections following the loss of the stationary vanes revealed only small pits in the rotating vane group that required minor refurbishment and balancing. The Owners' Group discussed this with the NRC staff and its consultants in a meeting in January 1985 and concluded that no further action was required to qualify this component. This conclusion remains valid as subsequent inspections have revealed no information that would invalidate this conclusion.

The Owners' Group has determined that periodic overhauls of the turbocharger are required. The inspection of 38 turbochargers provides a well-documented basis for determining the appropriate overhaul frequency. These inspection results, coupled with an understanding of the impact of bearing wear on engine performance, installation of prelube systems to limit wear, and the availability of effective monitoring techniques will allow the TDI licensees to determine when turbocharger overhaul is required. In general, the data would indicate an overhaul frequency of once every five years. Similar data for non-nuclear engines show a need to overhaul turbochargers every 8,000 to 10,000 hours. The Owners' Group diesel management program will require monitoring and trending of parameters which would provide an early warning and need for an overhaul if problems develop. Cylinder exhaust temperatures would be monitored to assure that operation above the design temperature limit of the component does not occur. Sustained operation above this limit could result in degraded performance. Vibration monitoring and variances in base line information would indicate an out-of-balance state resulting in premature bearing wear and other problems. Measurement and tracking of the thrust bearing wear will indicate remaining life of the bearing.

APPENDIX B

SUMMARY OF RECOMMENDATIONS BY THREE DIESEL GENERATOR EXPERTS

Three recognized diesel experts, Messrs. Paul Louzecki, Adam Henriksen and B.J. Kirkwood participated in a review of the operational database and inspection results submitted by the Owners' Group. A summary of their recommendations and staffs evaluation of the recommendations are as follows:

Mr. Paul Louzecki offered these specific recommendations:

- Power output should be maintained at currently authorized loads for the River Bend station because of torsional vibration considerations and Grand Gulf because of connecting bolt size.
- TDI engines have experienced water pump problems due to torsional vibrations and wear. The Owners' Group should inspect/replace/refurbish these pumps on a schedule that will avoid failures. Design changes may also be considered.
- Connecting rod bolts on the 16 cylinder engines, should be checked for tightness every other refueling outage as part of the TDI Owners' Group program.
- Since TDI engines do not have many accumulated hours, even after 10 years in nuclear service, compared to more normal service engines, with correct monitoring and supporting program elements, it seems unnecessary to have mandatory overhauls at 10-year intervals.

The staff evaluated Mr. Louzecki's recommendations and determined that they have been factored in the Owners' Group diesel management program. The power outputs at the River Bend and Grand Gulf stations will continue to be maintained at the currently authorized loads.

Mr. Adam Henriksen offered a specific recommendation concerning the management of engines that exceed power ratings by more than insignificant time/power parameters or that operate at critical torsional conditions. He recommended a 750-hour operational run to verify absence of new fatigue sensitivity due to the abnormal operation. He also noted that as each unit completes 750 hours of operation, crankshaft and other fatigue-based inspections could be eliminated.

In addition, Mr. Henrikson offered the following:

- Deterioration of the O-ring seals between the cylinder liner and the engine block is a special consideration in establishing the correct overhaul period. This deterioration is primarily a function of time and, to some degree, it may be affected by excessive piston impact. Pulling samples of liners to determine the O-ring condition is the only means for monitoring its condition in considering an extension of the overhaul period. Within the current 10-year period, this seal is not expected to leak. In this application of static O-ring service, considerable elasticity can be lost before leakage becomes a danger.

- Connecting rod bolts should be checked for tightness every five years as part of the TDI Owners' Group program.

- In addition to maintaining the surveillance requirements outlined in NUREG/CR-5057, cylinder compression, maximum pressures and cylinder leak-down testing (cold engine) should be checked during refueling outages.

The staff concurs with Mr. Henrikson's recommendations concerning the management of engines that exceed power ratings. The Owners' Group diesel management program will have comparable requirements to verify that abnormally-high torsional stresses have not been imposed. There are adequate provisions in the diesel management program to determine the condition of the O-ring seals and tightness of the connecting rod bolts. The other surveillance requirements recommended by Mr. Henrikson will also be included in the diesel management program.

Mr. B. J. Kirkwood offered two specific recommendations:

- The 10-year inspection of nuclear service TDI engines is important. It seems necessary to have completed at least a few TDI engine overhauls after 10-year intervals to be able to judge the further adjustment to another time period.

- Turbochargers remain a concern. The risk of severe damage/failure is great from loose metallic components being ingested into rotating turbo charger sections. Current preventive maintenance requirements relative to turbochargers are important and should be continued by the Owners' Group. It seems necessary to have completed at least a few TDI turbocharger overhauls after 5 and 10-year intervals, to be able to judge the adjustment in maintenance requirements and/or schedule.

The staff evaluated Mr. Kirkwood's recommendations and concluded that, the license conditions requiring 10-year teardown inspections are no longer necessary on the basis of: (1) a review of the operational database and inspection results of key EDG components; (2) high-median reliability of TDI diesels; (3) potentially-negative consequences of intrusive inspections, and, (4) the Owners' Group's commitment to a comprehensive diesel management program developed in agreement with the engine manufacturer. The preventive maintenance requirements relative to turbochargers are included in the Owners' Group diesel management program.

APPENDIX C

IMPORTANT FEATURES OF A DIESEL GENERATOR PREVENTIVE MAINTENANCE PROGRAM

In the development of the preventive maintenance program, a number of key features should be reviewed to provide assurance that the maintenance program will successfully achieve the reliability goals.

The first and most important feature that is necessary for a successful maintenance program is that the engineering conditions that are to be monitored as part of the program must be explicitly identified. Although the Owners' Group Program contains a good representative list of items to be monitored, each plant may wish to institute its own scheme, in order to treat the particular problems experienced by each licensee. Because there appear to be differences in the reliability problems experienced by different plants, even among those using the same types of diesels, each plant must provide at least a nominal justification for the particular choice of a set of engineering conditions that it will monitor. It is not necessary for any plant to monitor <u>all</u> engineering conditions identified--only those important conditions that could prevent the emergency diesel generator (EDG) from achieving the reliability target.

Listed below are specific attributes that should be addressed by the diesel generator user:

- Monitoring of all key parameters such as temperatures (cooing water, lube oil, bearing, exhaust gases), pressures (cylinders, fuel, lube oil, air), speed, torque, load, or vibration levels.
- Establishing of sufficient test points for each parameter.
- Calibration and accuracy of monitoring equipment over time.
- Ensuring the rapid response of the monitoring equipment for adequate correlation of operating changes and parameter variations particularly under test conditions.
- Establishing the requisite frequency and accuracy of the data recorded.
- Ensuring the accurate recording (time, type, quantity) of all additions of fuel, lube oil, cooling water treatment chemicals, etc.
- Establishing the requisite frequency for sampling of all fluids (fuel, lube oil, cooling water).
- Ensuring that the fluid samples are representative (sampling point, volume, time at which the sample is taken in relation to other events) and that the analyses are properly specified.

- Ensuring accurate recording (time, duration) of all operations of drains, blowdowns, and vents, along with the reasons for these operations.
- Ensuring that the engine data are being reviewed and analyzed on a regular basis and that remedial measures are taken, when necessary, in a timely manner.

The criteria for data analysis and corrective actions which include alert levels must be clearly identified for each of the engineering conditions contained in the set to be monitored as part of the EDG condition monitoring program. Alert levels are normally as simple as a minimum and/or maximum value for a parameter or a trend in a parameter. They also include combinations of condition levels (e.g., high crankcase pressure coupled with high temperature). A single engineering condition may have a multiplicity of alert levels, some of which merely alert the operator that a long-term phenomenon is continuing to progress at some rate toward eventual degradation. An example is the continuous change in acoustic vibration level at a given set of frequencies that may be tied to some wearout phenomena. The actual "alert" may be a spectrum frequency level whereby the decision may be made, for the sake of prudence, to overhaul a portion of the EDG at the next scheduled reactor shutdown. Thus, the alert may require immediate action, or may simply result in a preventive maintenance action at some specified time in the future. Both the alert level value and a simple statement of the probable action to be taken should be presented as part of the condition monitoring plan.

The EDG condition monitoring program should be formalized in a set of procedures that contain checklists for the conditions monitored, monitoring frequencies, alert levels, and action statements for plant use. These checklists should contain the condition monitoring frequency, since there are separate checklists for checks per shift, per day, per week, etc. Alert levels and action statements would be condition specific and are highly dependent on the expected lag-time between observation of the engineering condition and the EDG failure mode related to the condition; severity of EDG failure mode related to the observed condition; and EDG repair outage time to correct the observed condition, compared to the repair outage time required if the condition were allowed to proceed to failure. These considerations should be implicit in the condition monitoring procedures.

As previously discussed, the frequencies with which the various EDG engineering conditions are to be sampled, or monitored, depend on the nature of the conditions and how they are related to the EDG failure mode that is being protected against. These frequencies must be set on the basis of the expected lag-time from observing the failure precursor condition to the subsequent failure mode; whether the observed condition is a direct observation of a condition that will eventually result in deteriorated reliability; and the severity of the failure if the failure mode were to occur. These considerations must be explicitly discussed in the condition monitoring frequency justification.

It is generally beneficial from the standpoint of EDG availability to incur EDG outage time for the purpose of condition monitoring, which leads to preventive maintenance, in order to avoid the subsequent EDG failures that would be experienced had the preventive maintenance not been performed. However, it is still incumbent upon the licensee to ensure that EDG outages for condition monitoring and preventive maintenance do not become excessive. That is, the licensee's condition monitoring program must reflect the tradeoff of EDG reliability between preventive maintenance and EDG failure (and subsequent corrective maintenance).

It is inevitable that the appropriate set of monitored parameters and frequency of monitoring will change over time. This is true for two reasons: (1) because of wear and aging mechanisms, the important EDG failure causes are expected to change with time and (2) additional failure information, and improved techniques for condition monitoring, will almost certainly result in a changed perception of the appropriate condition monitoring for an individual EDG. Therefore, it is important that the EDG maintenance program has provisions for periodically reviewing and updating the condition monitoring performed on the diesel generators.

APPENDIX D

The following is a sample of the license conditions that were imposed on TDI owner licensees based on recommendations in NUREG-1216, in 1986, and their removal is being approved by the staff in this SE.

(1) General (applicable to all TDI engines)

Changes to the maintenance/surveillance program for the TDI diesel engines, as identified in [ ]*, shall be subject to the provisions of 10 CFR 50.59.

The frequency of the major engine overhauls referred to in the license conditions below shall be consistent with Section IV.1, "Overhaul Frequency," in Revision 2 of Appendix II of the Design Review/Quality Revalidation Report that was transmitted by letter dated May 1, 1986, from J. B. George, Owners' Group, to H. R. Denton, NRC.

(2) Connecting Rods (applicable to TDI DSRV-16-4 and DSRV-20-4 engines only)

Connecting rods assemblies shall be subjected to the following inspections at each major engine overhaul:

- The surfaces of the rack teeth should be inspected for signs of fretting. If fretting has occurred, it should be subject to an engineering evaluation for appropriate corrective action.
- All connecting rod bolts should be lubricated in accordance with the engine manufacturer's instructions and torqued to the specifications of the manufacturer. The lengths of the two pairs of bolts above the crankpin should be measured ultrasonically before and after tensioning.
- The lengths of the two pairs of bolts above the crankpin should be measured ultrasonically before detensioning and disassembly of the bolts. If bolt tension is less than 93% of the value at installation, the cause should be determined, appropriate corrective action should be taken, and the interval between checks of bolt tension should be reevaluated.
- All connecting rod bolts should be visually inspected for thread damage (e.g., galling), and the two pairs of connecting rod bolts above the crankpin should be inspected by magnetic particle testing to verify the continued absence of cracking. All washers used with the bolts should be examined visually for signs of galling or cracking, and replaced if damaged.

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*Appropriate license conditions differ from plant to plant.

- A visual inspection should be performed of all external surfaces of the link rod box to verify the absence of any signs of service-induced stress.

- All of the bolt holes in the link rod box should be inspected for thread damage (e.g., galling) or other signs of abnormalities. In addition, the bolt holes subject to the highest stresses (i.e, the pair immediately above the crankpin) should be examined with an appropriate nondestructive method to verify the continued absence of cracking. Any indications should be recorded for engineering evaluation and appropriate corrective action.

The following item applies only to DSRV engines with connecting rods employing 1-7/8-in.-diameter bolts:

- The following actions should be performed if the engines are operated in excess of 5740 kW:

  (Specific actions have not yet been developed.)

(3) <u>Crankshafts</u> (applicable to TDI DSR-48 engines at Rancho Seco)

- During the first refueling outage, inspect the fillets and oil holes of the three most heavily loaded crankpin journals (Nos. 5, 6, and 7) in each crankshaft, using liquid penetrant. Indications found should also be evaluated with eddy current methods as appropriate.

- During the second and third refueling outage, inspect the fillets and oil holes of the three most heavily loaded crankpin journals in each crankshaft, using liquid penetrant. Indications found should also be evaluated with eddy current methods as appropriate.

- During each major engine overhaul, inspect the fillets and oil holes of the (a) three most heavily loaded crankpin journals (Nos. 5, 6, and 7) and (b) the main journals located between crankpin journals 5, 6, and 7.

- The following actions shall be performed if the engines are operated in excess of an indicated load of [31340 Kw]:[*],[**]

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[*] Momentary transients (not exceeding 5 sec) that result from changing bus loads need not be considered as an overload.

[**] The figures shown in brackets are for River Bend, which has a qualified load capacity of 3130 Kw. For Rancho Seco, different values may be appropriate depending on the value of the qualified load established for the Rancho Seco TDI engine crankshafts.

(a) For indicated engine loads in the range of [3130 Kw] to [3200 Kw] for a period of less than 2 hours,[*] no additional action shall be required.

(b) For indicated engine loads in the range of [3130 Kw] to [3200 Kw] for a period of equal to or exceeding 2 hours,[*] a crankshaft inspection pursuant to item d (below) shall be performed at the next refueling outage.

(c) For indicated engine loads in the range of [3200 kW] to [3500 kW] for a period of less than 1 hour,[*] a crankshaftinspection pursuant to item d (below) shall be performed for the affected engine at the next refueling outage.

(d) For indicated engine loads in the range of [3200 kW] to [3500 kW] for a periods equal to or exceeding 1 hour,[*] and for engine loads exceeding [3500 kW] for any period of time, (i) the engine shall be removed from service as soon as safely possible, (ii) the engine shall be declared inoperable, and (iii) the crankshaft shall be inspected. The crankshaft inspection shall include crankpin journals 5, 6, and 7 (the most heavily loaded) and the two main journals in between, using liquid penetrant. Indications found should be evaluated with eddy current testing as appropriate.

If cracks are found during inspections of crankshafts, this condition shall be reported promptly to the NRC staff and the affected engine shall be considered inoperable. The engine shall not be restored to "operable status" until the proposed disposition and/or corrective actions have been approved by the NRC staff.

(4) Crankshafts (applicable only to DSRV-20-4 crankshafts at San Onofre Unit 1)

- Oil hole locations in the five most heavily loaded main journals (i.e., journals 8 through 12) for each crankshaft shall be inspected at each refueling outage with liquid penetrant. Indications found shall be evaluated with eddy current testing as appropriate.
- During each major engine overhaul, the fillets of the most heavily loaded main journals (Nos. 4 through 12) should be inspected together with the oil holes, using liquid penetrant. Indications found shall be evaluated with eddy current testing as appropriate. In addition, these inspections should be performed for the oil holes and fillets in at east three of the crankpin journals at each major engine overhaul.

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[*] If there are multiple overload events within a given load range since the previous crankshaft inspection, then the time criterion applies to the total accumulated time in that load range.

- The following actions shall be performed if the engines are operated in excess of 4500 kW (+5%):

  (NOTE: Specific actions applicable to San Onofre Unit 1 have not yet been developed. These actions should be specified in a manner similar to that used for River Bend.)

If cracks are found during inspections of crankshafts, this condition shall be reported promptly to the NRC staff and the affected engine shall be considered inoperable. The engine shall not be restored to "operable status" until the proposed disposition and/or corrective actions have been approved by the NRC staff.

(5) Cylinder Blocks (applicable to all TDI engines)

- Cylinder blocks shall be inspected for "ligament" cracks, "stud-to-stud" cracks and "stud-to-end" cracks as defined in a report** by Failure Analysis Associates, Inc. (FaAA) entitled "Design Review of TDI R-4 and RV-4 Series Emergency Diesel Generator Cylinder Blocks" (FaAA Report No. FaAA-84-9-11.1) and dated December 1984. (Note that the FaAA report specifies additional inspections to be performed for blocks with "known" or "assumed" ligament cracks.) The inspection intervals (i.e., frequency) shall not exceed the intervals calculated using the cumulative damage index model in the subject FaAA report. In addition, inspection methods shall be consistent with or equivalent to those identified in the subject FaAA report.

- In addition to inspections specified in the aforementioned FaAA report, blocks with "known" or "assumed" ligament cracks (as defined in the FaAA report) should be inspected at each refueling outage to determine whether or not cracks have initiated on the top surface, which was exposed because of the removal of two or more cylinder heads. This process should be repeated over several refueling outages until the entire block has been inspected. Liquid penetrant testing or a similar sensitive nondestructive testing technique should be used to detect cracking, and eddy current testing should be used as appropriate to determine the depth of any cracks discovered.

- If inspection reveals cracks in the cylinder blocks between stud holes of adjacent cylinders ("stud-to-stud" cracks) or "stud-to-end" cracks, this condition shall be reported promptly to the NRC staff and the affected engine shall be considered inoperable. The engine shall not be restored to "operable status" until the proposed disposition and/or corrective actions have been approved by the NRC staff.

**This report was transmitted to H. R. Denton, NRC, from C. L. Ray, Jr., TDI Owners' Group, by letter dated December 11, 1984.

(6) Cylinder Heads (applicable to all TDI engines)

The following air-roll test shall be performed as specified below, except when the plant is already in an Action statement of Technical Specification 3/4.8.1, "Electric Power Systems, A.C. Sources":

The engine shall be rolled over with the airstart system and with the cylinder stopcocks open before each planned start, unless that start occurs within 4 hours of a shutdown. The engines shall also be rolled over with the airstart system and with the cylinder stopcocks open after 4 hours, but no more than 8 hours, after engine shutdown and then rolled over once again approximately 24 hours after each shutdown. (If an engine is removed from service for any reason other than the rolling-over procedure before expiration of the 8-hour or 24-hour periods noted above, that engine need not be rolled over while it is out of service. The licensee shall air-roll the engine over with the stopcocks open at the time it is returned to service.) The origin of any water detected in the cylinder must be determined, and any cylinder head that leaks because of a crack shall be replaced. The above air-roll test may be discontinued following the first refueling outage subject to the following conditions:

- All cylinder heads are Group III heads (i.e., cast after September 1980).
- Quality revalidation inspections, as identified in the Design Review/Quality Revalidation report, have been completed for all cylinder heads.
- Group III heads continue to demonstrate leak-free performance. This should be confirmed with TDI before air-roll tests are discontinued.

(7) Piston Skirts (applicable to modified type AF piston skirts only)

- The stud boss attachments of the modified type AF piston skirts shall be inspected with liquid penetrant at each major engine overhaul. Indications found should also be inspected with eddy current methods as appropriate. (This license condition may be deleted for individual piston skirts after they have completed 750 hours of service at engine loads equaling 4500 kW (+5%)):
- The following actions shall be performed if the engines are operated in excess of 4500 kW (+5%):

  (Specific actions have not yet been developed.)

(8) Turbochargers (applicable to Elliot Model 65G and 90G turbochargers of all TDI engines)

Periodic inspections of the turbochargers shall include the following:

- The turbocharger thrust bearings should be visually inspected for excessive wear after 40 nonprelubed starts since the previous visual inspection.

- Turbocharger rotor axial clearance should be measured at each refueling outage to verify compliance with TDI/Elliott specifications. In addition, thrust bearing measurements should be compared with measurements taken previously to determine a need for further inspection or corrective action.

- Spectrographic and ferrographic engine oil analysis shall be performed quarterly to provide early evidence of bearing degradation. Particular attention should be paid to copper level and particulate size, which could signify thrust bearing degradation.

- The nozzle ring components and inlet guide vanes should be visually inspected at each refueling outage for missing parts or parts showing distress on a one-turbocharger-per-refueling-outage basis. In addition, these inspections should be performed for all turbochargers at each turbocharger overhaul (i.e., at approximately 5-year intervals). If any missing parts or distress is noted, the entire ring assembly should be replaced and the subject turbocharger should be reinspected at the next refueling outage.

APPENDIX E

COMPONENTS REQUIRING ENGINE LOAD LIMITS AND/OR SPECIAL ROUTINE MAINTENANCE AND SURVEILLANCE

Component	Engine load limited	Special maintenance and surveillance required
Crankshaft		
DSR-48	Yes	Yes
DSRV-48	Yes*	Yes
Cylinder block		
DSR-48 (Shoreham)	No	Yes
DSRV-16 (Comanche Peak)	No	Yes
Cylinder heads	No	Yes
Connecting rods		
DSRV engines, 1-7/8-in. bolts	Yes	Yes
DSRV engines, 1-1/2-in. bolts	No	Yes
Piston skirts		
Type AF	Yes	Yes
Turbocharger	No	Yes

*Limitations on engine testing have been established to minimize crankshaft torsional stresses during startup transients.

Abstract

This topical report (*TDI-EDG-001-A, "Basis for Modification to Inspection Requirements For Transamerica Delaval, Inc., Emergency Diesel Generators"*) is submitted to the U.S. Nuclear Regulatory Commission (NRC) for docketing. This approved topical report provides justification for changes to inspection, maintenance, and surveillance requirements for TDI Emergency Diesel Generators to improve availability and maintain reliability. The NRC Staff issued its Safety Evaluation Report (SER) approving this topical report on March 17, 1994. The NRC's SER has been incorporated into this topical report as requested by the NRC in its March 17, 1994, letter to the TDI Owners Group.

As demonstrated in this topical report and confirmed in the NRC's SER, there is adequate justification for removing the present component-based licensing conditions. The TDI EDGs should be treated on par with other EDGs within the nuclear industry and subjected to the same standard regulations, without the special requirements of NUREG-1216, "Safety Evaluation Report Related to the Operability and Reliability of Emergency Diesel Generators Manufactured by Transamerica Delaval, Inc.," (August 1986).

This report contains the following previous submittals of information to the NRC.

A) **Licensing Submittal on Behalf of the Transamerica DeLaval,Inc., Owners Group for Review of Licensing Conditions Imposed by NUREG-1216**. This report dated November 30, 1992, and submitted to the NRC by letter dated December 8, 1992, provided background and information related to seven years of inspections and teardowns required by NUREG-1216. This report is identified as Reference (2) on page 12 of the SER.

B) **Licensing Submittal on Behalf of the Transamerica DeLaval,Inc., Owners Group for Review of Licensing Conditions Imposed by NUREG-1216, Revision 1.** This report dated May 3, 1993, and submitted to the NRC by letter dated May 3, 1993, provided clarification on the inspections and teardowns summarized in the November 30, 1992 report.

Abstract

C) **Generic Licensing Submittal No. 2 for Emergency Diesel Generators Conditions of License for Utilities with Enterprise Engines**. This report submitted to the NRC by letter dated December 7, 1993, provided the following information:

   i) discussion of inspection results and conclusions for certain diesel engine components

   ii) a sample data table indicating results of inspections for an engine component(s)

   iii) data table providing inspection results for certain diesel engine components

   iv) summary of diesel engine inspection wording found in each TDI Owner's Technical Specifications

D) The TDI Owners Group also provided information to the NRC by letter dated December 21, 1993. This letter provided additional information regarding available outage windows for engine teardown and overhauls and fast start capability.

NUCLEAR REGULATORY COMMISSION

LICENSING SUBMITTAL

ON BEHALF OF

THE TRANSAMERICA DELAVAL, INC., OWNERS GROUP

FOR REVIEW OF

LICENSING CONDITIONS IMPOSED BY NUREG 1216

THE TRANSAMERICA DELAVAL, INC. OWNERS GROUP
LICENSING CONDITIONS
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1.0 EXECUTIVE SUMMARY

The Transamerica Delaval, Inc. (TDI) Owners Group recommends the removal of the licensing conditions imposed by NUREG 1216. Based on substantial operating experience and the Design Review/Quality Revalidation (DR/QR) effort for the critical components, the TDI emergency diesel generator (EDG) has demonstrated that special concerns of NUREG 1216 are no longer warranted. Therefore, the TDI EDGs shall be regarded the same as other EDGs within the nuclear industry, and subjected to the standard regulations without the special requirements of NUREG 1216. These conclusions are supported by the information that follows. In addition, this action will improve unavailability of the engines for service, especially during outages, while maintaining current low unreliability levels.

The TDI Owners Group therefore requests the NRC to review the revised recommendations contained within this report and issue a generic Safety Evaluation Report (SER) endorsing removal of the component based License Conditions that are currently required by certain power plant Operating Licenses. This generic SER would then be referenced by individual licensees to process Operating License amendments on each docket for plant with TDI diesels to remove these License Conditions. All aspects of the maintenance and surveillance programs would then be controlled by the licensee and reviewed by the NRC under current regulations.

2.0 INTRODUCTION AND BACKGROUND

The Design Review/Quality Revalidation (DR/QR) effort of 1984 has been performed on Emergency Diesel Generators (EDG) supplying emergency AC power for the following utilities that are in support of this licensing submittal:

UTILITY	STATION
Texas Utilities, Inc	Comanche Peak
Entergy Operations, Inc.	Grand Gulf
Duke Power, Inc.	Catawba
Carolina Power and Light, Inc.	Shearon Harris
Georgia Power/Southern Nuclear Operating, Inc.	Vogtle
Cleveland Electric Illuminating Co./Centerior Energy	Perry
Gulf States Utilities, Inc.	River Bend
Tennessee Valley Authority	Bellefonte

(Note that not all engines at all plants have completed DR/QR as indicated in the particular docket; but each utility has a representative sample of engines that have completed this inspection and have operational hours since the inspections). This effort was in response to NRC concerns regarding the reliability of large-bore, medium speed diesel generators manufactured by TDI for application at nuclear power plants. Southern California Edison remains a current member of the Owners Group, however due to a decision to decommission, Unit 1 of the San Onofre plant is not a participant in this action. Long Island Lighting and Sacramento Municipal Utility District have ceased membership in the Group due to decommissioning actions and are not participating in this action. Washington Public Power Supply and Consumers Power have deferred or canceled plants and are not a participant in this action. This accounts for the thirteen utilities that originally began development of the DR/QR effort.

This effort was originally outlined and documented with the NRC as the TDI Owner Group Program Plan. This plan was accepted by the NRC in an Safety Evaluation Report (SER) dated August 13, 1984. Following issuance of the SER, the Owners Group member utilities developed and implemented the DR/QR in response to the Program Plan. The specific details of the DR/QR were submitted to the NRC for review and this information was reviewed and referenced as part of the NRC position which was documented in NUREG 1216. The recommendations of the NRC consultants hired to assist in this effort is also referenced in NUREG 1216 and is documented in PNL-5600. These details resulted in specific license conditions for each utility as the individual DR/QR reports were submitted under the utilities respective dockets. These utilities have operated for a substantial time period and logged many operation hours on these EDGs and this operational data is being submitted for review to remove the license conditions imposed by NUREG 1216. It should be noted that the scope of the original NRC review was to look in detail at the Phase I components as defined by the DR/QR program.

NUREG-1216 documents the NRC reviews of Phase I and II components. Phase I components are addressed later in this submittal. Phase II components constitute approximately 150-170 components on the engine. The NRC review of Phase II components documented in NUREG-1216 concluded that a detailed review of these items was not necessary and would be redundant.

The Phase I components were chosen as those that had potential for generic concerns. Through an extensive review of TDI and other engine performance data in both nuclear and non-nuclear applications, the Owners Group identified 16 components with such concerns. These are:

air start valve capscrews
connecting rods
connecting rod bearing shells
crankshafts
engine base and bearing caps
engine mounted electrical cable
high pressure fuel injection tubing
jacket water pump

cylinder block

cylinder heads

cylinder head studs

cylinder liners

piston skirts

push rods

rocker arm capscrews

turbochargers

These engines have operated under the requirements of the program reviewed and approved by NUREG 1216. This document presents the results of the operation of a large sample of engines under that program and demonstrates that the reliability of these engines is comparable to the reliability of other EDGs and that the time required to continue to perform teardowns and inspections as outlined in specific licensing conditions substantially adds to the unavailability of the engines. Subject to the findings of this report, the Owners Group concludes that these engines can be operated in a safe manner without degrading reliability and still achieve improvements in unavailability by removing license conditions to perform inspections requiring engine teardown.

The Owners Group will develop a performance based maintenance program outside of the licensing environment to assure that the goals outlined above will continue to be met.

3.0 COMPONENT PERFORMANCE REVIEW

This section discusses the original component concerns, the proposed modifications/inspections that were subsequently required, the results of the modifications/inspections, and a proposed disposition of each item. The modifications/inspections that will be discussed are listed in the DR/QR report, Appendix II, Part B. A copy of the current version of Parts A and B of this Appendix is included as a part of this submittal as Appendix A. Appendix A and NUREG 1216 are the basis for the license conditions that are imposed on some utility dockets. The original review contained in the above documents along with the results of the inspections performed since that initial review was completed will be the review basis for the amended recommendations to be approved by the NRC.

3.1 ENGINE OVERHAUL FREQUENCY

The overhaul frequency for the TDI engines was originally recommended to occur at an approximate 5 year interval. This interval was later revised to 10 years because (1) of the comprehensive DR/QR effort conducted for each of the engine components, (2) of the limited number of operating hours for the engines in nuclear standby service, and (3) a sample inspection of major engine components will be performed on a one-time basis following 5 years of service. Details of the results of inspections performed during this teardown are outlined in the discussion of the individual components. Overall, the teardowns did not indicate any major problems or suggest that any component had experienced any significant wear. The average number of operating hours logged on an engine in a year is approximately 100 hours. This number is much less than the number of hours typically experienced by non nuclear engines. This mode of operation lends itself to using monitoring/surveillance programs in lieu of hours of operation to determine overhaul frequencies.

Collectively, these engines have accumulated over 9000 hours of operation. This provides a significant data base on which to base removal of the license conditions imposed by NUREG 1216.

Recent studies performed for the NRC (Reference: NUREG/CR-5078, PNL-6287) indicate that for approximately 2 years following a major engine overhaul, EDGs, regardless of their manufacturer, exhibit increased unreliability. This increase is attributed to several reasons. One reason offered is that during disassembly there is a high potential to introduce dirt and other substances that may harm the engine. Another is that disturbing a precision fit system that "wears in" to seat mating surfaces (eg rings and liners, crankshafts and bearings, connecting rods and bearings) can result in alteration of wear patterns that may increase wear or actually cause wear to start and decrease the life of the component. As noted in the above reference, the period following overhaul is a "shakedown" period that is required to produce smooth running reliable engine.

The Owners Group agrees with the findings of the above study. In addition, the results of the 5 year "mini" overhauls have shown no component failures that resulted in a loss of component function and have also shown that operational component wear since installation has been very minimal. To perform a complete engine overhaul for a typical engine could take approximately six weeks during an outage and could make the diesel more unavailable during the outage. Extending the period between overhauls reduces the overall cost that would be incurred for additional parts and labor to install and refurbish components that are no worse from wear than the new parts to be installed. In order to prevent increased unreliability and to reduce unavailability, the Owners Group recommends that an overall frequency not be specified. Individual utilities will use maintenance/monitoring and trending data similar to the information gathered in Table 1 of Appendix II of the DR/QR report, and coupled with the engine manufacturer's recommendations, to determine when a particular component would need refurbishment or replacement. This would give the utility the flexibility to plan for this work to be performed over an appropriate period in lieu of one outage period and would serve to reduce unavailability and unreliability.

3.2 AIR START VALVE CAPSCREWS

PM Recommendations

There are no PM recommendations associated with this component in Part B, Appendix A. Revision 2 of Part B, Appendix A recommended that upon installation of a new capscrew, retorquing should be performed at specified intervals to compensate for gasket creep. When no change in torque is detected, the gasket is fully compressed and the torque will be maintained. This item was removed by revision 3 to Part B as the manufacturer has agreed that this is a proper recommendation and has put this item in their PM recommendations.

Background

The air start valve capscrew have not had a history of failure. The original concern with the component dealt with the component being too long and "bottoming out" in the cylinder head. In SIM 360, TDI recommended a change to use a shorter capscrew and recommended a suitable torque value. This was in response to reports at Shoreham and Grand Gulf where these capscrews had been found to loosen.

Results of Inspections

Loosening of this component or other related problems have not been detected since the utility has either made the change noted above or has verified that the existing capscrew does not bottom out. All capscrews have been properly torqued. This is the justification for removal of this item from Part B and placing this information with the vendor recommendations.

Conclusions

This item was closed under NUREG 1216 and no further problems have been reported. Utilities should continue to follow vendor torquing procedures upon replacement.

3.3 ENGINE MOUNTED ELECTRICAL CABLE

PM Recommendations

There are no PM recommendations associated with this component in Part B, Appendix A.

Background

TDI SIM 361, revision 1 notified the engine owners of potentially defective engine-mounted cables associated with the Woodward governor/actuator and the AIR-Pax magnetic pickup. This memo led the Owner's Group to review in detail the suitability of all class IE auxiliary module wiring and terminations currently installed on the diesel engines. Of special interest was the suitability of this wiring with respect to flame-retardancy of the insulation, qualification to industry standards, routing of conduit, compatibility with circuit requirements, and the need for special requirements such as shielding. Modifications were, in some cases, recommended and all of these modifications were completed.

Results of Inspections

No further problems or issues have been found dealing with this component.

Conclusions

The modifications specified address the concerns with this component and this issue was closed during the initial NRC review. This item was closed under NUREG 1216 with no additional concerns found since that time and this item remains closed.

3.4 ENGINE BASE AND BEARING CAPS

PM Recommendations

The base and bearing caps preventative inspections are listed in Part B of Appendix A. Specifically, PM recommendation 1 can be made without a disassembly; PM recommendation 2 does require disassembly but is only required to be performed when the caps are removed for other reasons.

Background

The original Owner's Group design review for this component found adequate factors of safety for all components. Problems encountered with this component are not generic in the engines supplied for nuclear service. Problems that were encountered were with non nuclear service engines resulting from inadequate bolt preload and in one case, marginal strength due to inferior quality of a casting. The NRC review noted specifically that once the caps are installed according to the Owner's Group recommendations and torqued to TDI specifications, they should not require further attention until they are removed for some other reason. It should be noted that inspections proposed in Part B of the maintenance matrix were to validate the findings of the analysis discussed above and were a conservative step to aid the licensing process.

Results of Inspections

For all engines in current service, a metallurgical exam for Widmanstaetten graphite has been made or the recommended three cycle inspection for cracks have been completed and none of the bases have indications of inferior material. Twenty-five separate base inspections have been made with no signs of cracks noted. In addition, hundreds of inspections have been made of the bearing cap and saddle interface for PM item 2 and no problems have been detected.

Conclusions

Based on the positive results of the monitoring and the conservative nature of the PMs, the base inspections should be no longer necessary. The inspection of the cap mating surfaces should continue as good maintenance practice only when the caps are removed for other reasons.

3.5 CONNECTING RODS

3.51 DSR-48 Inline Engine

PM Recommendations

The connecting rod preventative inspections are listed in Part B of Appendix A. Specifically, PMs 1,2,4, and 5 require teardowns to perform. PM item 3 is excluded from this discussion as it is the scope of a previous license submittal and is already under review by the NRC. These inspections have been performed on the River Bend engines as outlined in Appendix B.

Background

During the DR/QR review, only one rod failure was reported and that was on a non nuclear application and the failure was due to the possibility of pre-existing defects on the surface of the rod eye and to the higher peak firing pressures used in the engine that had the rod to fail.

The design review performed found no design problems with the rod. However, the NRC recommended that a rod eye and bushing be inspected using an acceptable NDE technique and that all bolts and washers be inspected at the same time.

Results of Inspections

The rods at River Bend have been inspected on a sampling basis at the 5 year interval with no problems found. This was performed on two connecting rods per engine and the associated bolts and washers and bearings.

Conclusions

Based on the initial design review and the positive inspection results it is concluded that these inspections should not be performed unless the rod is removed from the engine for other reasons. These inspections should be viewed as good maintenance practices and not as requirements.

3.52 DSRV-16 Engines

PM Recommendations

The connecting rod preventative inspections are listed in Part B of Appendix A. Specifically, all PMs with the exception of PM 9 require teardown to perform. PM item 3 is excluded from this discussion as it is the scope of a previous license submittal to the NRC and is already under review.

Background

During DR/QR review a total of six rod failures were documented. TDI had identified two failure mechanisms in SIM 349. The first was due to fatigue of the link rod bolts resulting from loss of bolt preload. The second mechanism was fatigue cracking of the connecting rod bolts and/or the link rod box in the mating threads. The Owner's Group Design review performed a detailed stress analysis of the rod and looked at fatigue as suggested by TDI. The results of that analysis showed the peak stresses induced by the loading mechanisms are slightly below the fatigue initiation curve for rods with 1-1/2" bolts and slightly above the fatigue initiation curve for rods with 1-7/8" bolts. Grand Gulf (Entergy) is the only utility that has engines with the 1-7/8" bolts still in use. The summary of this work is that as long as the bolts are properly torqued the rods will perform with no problems.

Results of Inspections

A total of 42 connecting rods have been completely disassembled and subjected to the PMs described above. A total of 1776 bolts have been checked for proper tension during the time since DR/QR. These inspections have revealed no problems and these rods continue to provide good service.

Conclusions

Based on the above, the Owner's Group recommends that further connecting rod disassembly to perform the inspections above on a particular time frequency is not warranted. However, it is the recommendation of the Group that as rods are removed from service for any reason, they should be subjected to the PMs in Appendix A as a good practice but this should not be a requirement. Oil analysis should continue to be performed as this will provide indication of premature bearing wear or bearing problems as babbitt will be recognizable in the oil. Also, vibration measurements should continue as well as operation monitoring which will also provide an indication of potential problems with this component.

The engines at Grand Gulf are currently limited to 185 BMEP. This derating reduces the stresses associated with fatigue cracking of connecting rod bolts and/or the link rod box. Based on past positive inspection results and engine derating, the recommendations for 1-1/2" bolting will then apply to Grand Gulf as well.

3.6 CONNECTING ROD BEARING SHELLS

This item has been covered in Section 3.5, Connecting Rods and in a previous license submittal currently under review with the NRC. The previous submittals are documented in letters to Mr. Om Chopra dated October 31,1991 and supplemented February 27, 1992 from Messrs JB George and RD Broome. Therefore this item is addressed by reference to previous submittals. (Copies of these submittals are included as Appendix C and D.)

3.7 HIGH PRESSURE FUEL INJECTION TUBING

PM Recommendations

The high pressure fuel injection tubing preventative inspections are listed in Part B of Appendix A. The PMs do not require teardown to perform; however, the requirement to eddy current the non shrouded tubing prior to bending does result in considerable cost and delay of replacement tubing. Use of shrouded tubing has been approved by the Owners Group and the vendor to provide protection of leakage that would potentially result in a fire hazard. Fire hazard and personnel safety are the primary concerns with failure of this component.

Background

The review of this component during the DR/QR process revealed that failures had occurred at Shoreham and Grand Gulf Nuclear Stations. A 10CFR21 notification was issued on 7/20/83 by TDI alerting Owners and the NRC of the condition and identified that the cause of the failure stemmed from a draw seam that acts as a stress riser on the inner surface of the tube. One of the points stated is that a draw seem is induced during the drawing phase of the manufacturing and generally will extend over most of the length of the tube and be readily detectable. The design review noted that the tubing is acceptable as long as no preexisting flaws greater than a depth of .0054" existed. This prompted the recommendation to eddy current the tubing prior to bending. The reason for the concern was to prevent leakage that could potentially result in a fire and for personnel safety.

Results of Inspections

The tubing is visually inspected for leaks during each engine run. Since the DR/QR effort, four tubing failures have occurred. This inspection has resulted in hundreds of inspections of this component. Most engines are now equipped with the shrouded tubing which permits the leak check to be performed by removal of a plug. Shrouded tubing is a double wall tube that contains the high pressure fuel spray in the event of a leak and prevents fire and hazards to personnel.

Conclusions

The Owners Group recommends that visual inspections for leaks continue during the engine runs. Any problems should be readily identified by this process. In addition, replacement tubing must be shrouded. Further, because of its double wall design, use of shrouded tubing would eliminate the need to eddy current this tubing and this requirement should be deleted for shrouded tubing.

3.8 CRANKSHAFTS

3.81 DSR-48 Series Engines

PM Recommendations

The site specific preventative inspections are listed in Part B of Appendix A. All of these inspections require disassembly to perform. These inspections have been performed on a per PM basis as detailed in Appendix B.

Background

In August 1983, the crankshaft in the EDG 102 engine at the Shoreham Nuclear Power Station fractured during plant preoperational tests. The fracture occurred at the crankpin journal of cylinder No.7 and involved the web connecting the crankpin to an adjacent main bearing journal. Following this failure, several cracks were discovered in the crankshafts of the other two TDI diesels at Shoreham. These crankshafts were found to be deficient and were replaced with a different design that increased the diameter of the crankpin from the original 11" to 12". The replacement crankshafts were analyzed by the Owner's Group and by NRC and found acceptable for use.

The EDG engines at the River Bend Nuclear Station have crankshafts of the same dimensions as the replacement shafts at Shoreham. However, the generators and flywheels differ between the two installations, resulting in differences in crankshaft torsional stresses. Also the fillet radii at Shoreham are shotpeened while those at River Bend are not. The review and inspection made by the Owner's Group found that there were no relevant indications in the oil holes of the crankpins. However, the analysis revealed that crankshaft torsional stresses in the Shoreham engines at an operational load of 3300kw was equivalent to the torsional stresses in the River Bend engines at an operational load of 3130kw which accounts for the differences in the torsional systems. Therefore, the River Bend engines have been derated for nuclear operation to 3130kw with the crankshafts that are currently installed.

Results of Inspections

The inspections that have been performed are in accordance with Appendix A and has been performed in number as indicated in Appendix B. No indications or problems have been found with this component.

Conclusion

Based on the positive inspection results and on the previous design review, the Owner's Group recommends that future inspections of the crankshaft are not warranted as required by the DR/QR as long as the engine is operated at loads below 3130kw. Should this load be exceeded for an extended period, the engine should be removed from service and the crankshaft inspected in accordance with current procedures. Should no indications be found, the unit may return to service and no further inspections made unless the load limit is again exceeded.

3.82 DSRV-16 Engines

PM Recommendations

The crankshaft preventative inspections are listed in Part B of Appendix A. All of these recommendations require teardown to perform.

Background

The crankshafts for the DSRV-16 engines have a crankpin diameter of 13" and the overall crankshaft length is approximately 20 feet 7 inches. These engines have eight crank throws with 16 pistons driven by 8 articulated connecting rod sets. Differences in the generators and flywheels at the various installations result in differences in the torsional stresses. Therefore, each of the crankshafts at each installation were individually evaluated.

The results of these investigations produced similar results. The results are that the component is adequate for its intended service at full rated load and the 110% rated overload. Extended operation at speeds at or near the fourth order torsional vibration frequency modes should be avoided. (These speeds have been documented in Owner's Group site specific reports.) In addition, the engine should not be operated for extended periods in an unbalanced condition.

Results of Inspections

Appendix B indicates how many times each of the inspections detailed in Appendix A have been performed. None of these inspections have produced any indication of cracking and most of the engines have operated above the period (750 hours) that would subject the crankshafts to a number of cyclic loadings to demonstrate unlimited fatigue life.

Conclusion

Based on the positive inspection results and the original design review, the Owner's Group recommends that future inspections as required by the DR/QR are not warranted and should be eliminated.

3.9 JACKET WATER PUMP

PM Recommendations

The jacket water pump preventative inspections are listed in Part B of Appendix A. All PM recommendations require teardown to perform.

Background

The pumps for the DSR-48 and DSRV-16 engines are somewhat different. The original design of the pump for the DSR-48 engines had two failures on the engines at Shoreham that resulted from a fatigue failure originating at the gear/shaft keyway. This pump was subsequently redesigned. The new design removed the keyway on the impeller end and changed the impeller material to ductile iron. The impeller is now driven through its interference fit on the shaft. This later pump design is installed on the engines at River Bend.

Pumps for the DSRV-16 engines were reviewed as a result of the problems with the model DSR-48 engines. At the time of the review, there were no reported failures and the desigr. review concluded that the pumps were capable of serving their intended function with no problems. Since the DR/QR, there are reports of drive gear failures on non-nuclear engines and these have been addressed through the 10CFR21 program. There have been no problems with the original concern related to the shaft, keyway and impeller. A very recent inspection at one utility has identified a potential concern that is currently under review.

Results of Inspections

There have been no failures of jacket water pumps in nuclear service since the design changes made as a result of the DR/QR review. Inspections performed as outlined in Appendix B reveal that some pitting of the gear teeth on DSRV-16 engines has occurred during the pump operation. The resolution of this issue will be dealt with through the 10CFR21 process. Additional problems related to the shaft, impeller and keyway have not been identified.

Conclusion

Based on the positive inspection history, future inspections of this component on a time dependent basis as a requirement is not warranted. However, should the pump be removed or an engine overhaul be necessary, the pump should be inspected per the existing guidance.

3.10 CYLINDER BLOCK/LINERS

PM Recommendations

The block preventative inspections are listed in Part B of Appendix A. Specifically, PM recommendations 1, 2, and 3 require teardowns. The PM for the cylinder liners does not require a teardown but removal of the injector for access to the liner is required for visual inspection.

Background

The cylinder block provides support for the upper-engine components and contains passageways for the engine cooling water. The block is subjected to both mechanical and thermal stresses and is a grey-iron casting. Although the cylinders in the DSRV-16 engines are arranged in two banks while those in the DSR-48 engines are in a single bank, the two configurations do not differ in block top thickness, cylinder head spacing, upper support of the cylinder liner, and the stud boss region that anchors the cylinder head studs. Minor design changes have been incorporated as a result of DR/QR to reduce the protrusion of the cylinder liner collar above the block top and to increase the cold radial clearance between the cylinder liner and the block, thereby reducing stresses in the block top. Cracks have been reported in cylinder blocks of both DSR-48 and DSRV-16 engines in nuclear and non-nuclear applications.

A thorough design review of this component was completed during the initial DR/QR review. The results of that review were that some of the castings made during the period may contain Widmanstaetten graphite which is an inclusion that weakens the grey iron casting. It was shown that blocks containing this material have a greater potential for crack development. However, it was also shown that should these cracks develop, regardless of the cause, that the block would continue to perform its intended design function and that the cracking would potentially produce a flow path for water to the block exterior. A cumulative fatigue usage index formula was created and an inspection frequency was established based on that usage. Further, it was noted by the Owner's Group and by the NRC that this analysis was conservative and that "If cumulative results of these inspections over several power plant fuel cycles show that one or more of the inspections reveal nothing of significance, the scope and frequency of the inspections could be reconsidered." (Source: PNL-5600)

Results of Inspections

Block top inspections have been performed in accordance with the numbers outlined in Appendix B. Note that some of these inspections are being performed on a partial basis; however, none of the inspections (including those of blocks with widmanstaetten graphite) have revealed any cracks. In addition, no significant liner wear or indications have been found. A 10CFR21 notice has been issued dealing with a different issue with liners and is currently under review by the Owner's Group.

Conclusion

Based on the positive inspection results, the Owner's Group recommends that future block top inspections be performed when a head is removed for other reasons for plants that have blocks with no widmanstaetten graphite. For those sites having blocks with widmanstaetten graphite, the recommendation is to perform a visual inspection of the block top under strong lighting during a test run once a refueling cycle. Should cracks be found, the engine should be evaluated for continued service and a more detailed inspection performed at the next available refueling outage.

3.11 PISTON SKIRTS

The scope of this review will be limited to Type AE piston skirts. These are the only type skirts currently used in nuclear applications.

PM Recommendations

The piston skirt preventative inspections are listed in Part B of Appendix A. Specifically, the PM listed requires disassembly of the engine .

Background

The design review of this component revealed that design stresses are within the allowables and that based on experimentally measured data, neither crack initiation nor propagation is expected to occur. The AE skirts were tested and validated during DR/QR. The purpose of this validation was to determine the calculated fatigue life of this component. Following the validation, a detailed inspection was made of these skirts with no problems found. These skirts have previously been approved by NRC for use at the rated engine loads and all engines in current service have been equipped with these skirts.

Results of Inspections

Thirty nine piston skirts have been removed and inspected in detail. No problems have been found with this component and these skirts continue to provide good service. See Appendix B for the numbers of inspections.

Conclusion

Based on the positive inspection results of this component and documented design quality, further inspections under the DR/QR program for this component are not required unless a piston is removed from the engine for some other reason.

3.12 CYLINDER HEADS

PM Recommendations

The cylinder head preventative inspections are listed in Part B of Appendix A. Specifically, PM 1 requires teardown.

Background

The basic cylinder head configuration is common to all TDI DSR-48 and DSRV-16 engines. However, during periods of manufacturing, TDI made changes to manufacturing practices, quality control, and design. The heads manufactured have been categorized into three groups: those cast prior to October 1978 are referred to as Group I, those cast between October, 1978 and September, 1980 are Group II, and those cast after September 1980 are Group III.

Cylinder heads in Group I and II are subject to core shift, inadequate control of solidification, and inadequate control of the Stellite valve seat weld deposition process. In addition, Group I heads are not stress relieved and are subject fatigue crack growth in thin areas. Heads in Group III are much less prone to all of these problems. Casting defects were found at Shoreham, Grand Gulf, Catawba, and Comanche Peak during the DR/QR process. The net result from the design reviews and flaws, would have been to allow leakage of jacket water to the exterior of the head or to the cylinder. Exterior leakage is of no real concern from a reliability standpoint, but leakage into a cylinder can result in major engine damage. As a result, the Owner's Group recommended that the engine be barred or air rolled prior to starting with the air start cocks open to detect any potential leakage.

Results of Inspections

Inspections have been performed as detailed in Appendix B. Indications were found on the exhaust valve stem during RFO 4 at River Bend. The indications were caused by a sharp chamfered edge on the rocker arm swivel pad and are direct result of excessive valve lash. The root cause of the excessive valve lash has been attributed to back pressure in the exhaust system during the start sequence of the engine. The chamfered edge on the swivel pad was removed by machining. An improved swivel pad has been developed by the vendor. A later inspection has found that removal of this sharp edge is preventing further damage to the valve stem. In addition, a water leak has been found on a head at River Bend and this leak is under investigation to determine its cause.

Conclusions

Based on the above positive inspection results, PM recommendation 1 is not warranted and should be discontinued. It is the recommendation of the Owner's Group that pre run air rolls and inspections for leaks, prior to any planned start or as dictated by plant configuration, continue to preclude a leak from resulting in major engine damage. Any other type of degradation that could occur will become evident during compression checks, with exhaust temperature monitoring, and monitoring jacket water standpipe level for losses.

3.13 PUSH RODS

The scope of this review will be limited to push rods of the friction welded design.

PM Recommendations

The push rod preventative maintenance inspections are listed in Part B of Appendix A. The recommendation requires an engine teardown .

Background

Design analysis of this design showed that potential buckling under the loads to be imposed was not a concern. Metallurgical evaluations showed no major discrepancies in the chemical composition, hardness, or microstructures of any components. A fatigue crack growth analysis showed that, under cyclic loading, no potential fabrication cracks are expected to propagate in either the main or intermediate push rods using this design. A fatigue test that included 10 to the seventh cycles compressive load from zero load to a value approximately 25% above the maximum theoretical service load, was also conducted. No cracks or indications were found.

Results of Inspections

Over 900 push rods have been inspected following extended service and have shown no problems.

Conclusions

Based on the positive inspection results and the conservatism of the design, future inspections as required in the DR/QR are not warranted and the Owner's Group proposes to delete this item. Should these components be removed for other reasons, Owner's may elect to conduct these inspections depending on the service life and reasons resulting in engine teardown.

3.14 CYLINDER HEAD STUDS

This issue was closed in the original NRC review resulting in no preventative inspections for this component. There has been nothing found in subsequent operation of these engines to change this finding.

3.15 ROCKER ARM CAPSCREWS

PM Recommendations

The rocker arm preventative maintenance inspections are listed in Part B of Appendix A. The inspection is a "one time" inspection and has been completed for all engines. The inspection does require teardown.

Background

The review during the initial DR/QR revealed that capscrews failures had occurred on an isolated basis. The cause of the failures was due to insufficient preload on the capscrews. This failure history resulted in the requirements outlined under the PM Recommendations. The Owners' Group performed a detail design review of the component which calculated appropriate resultant stresses, endurance limits, and looked at the material requirements to determine that the material is suitable.

Results of Inspections

Subsequent to incorporating the torque requirements there have been over 500 inspections of this component with no major problems found. River Bend has reported two pop rivets missing; this was disposition as not being a problem as lubrication could still get to the needed areas.

Conclusion

This inspection is currently performed only on reassembly of the rocker arms. This should continue when the rocker arm is removed from service for any reason.

3.16 TURBOCHARGERS

PM Recommendations

The turbocharger preventative inspections are listed in Part B of Appendix A. Specifically, PM Recommendations 2,4,5, and 6 require teardowns. These inspections have been performed on a per PM basis as detailed in Appendix B. These turbochargers typically see operation hours of approximately 500 hours per 5 year interval.

Background

Turbocharger performance directly affects the design rating of the engine. During the DR/QR review, several bearing and lubrication problems were identified. In addition, there was a concern dealing with the potential for damage of the rotating vane group due to ingesting fragments of material, specifically bolts and blades from the stationary vanes assembly that had failed due to fatigue loadings. The response to these concerns were answered as follows:

1) Lubrication and Bearing Wear

The Owners Group recommended modifications to install the drip and full flow prelubrication system to provide an oil film to the turbo bearings that would drain away during standby and that this system should be activated to prelube any planned start. This recommendation has been implemented by the Owners. In addition, oil sampling was recommended as a means to detect significant bearing wear. PM items 1,3 and 4 relate specifically to this concern.

2) Potential For Damage to Rotating Vanes

During DR/QR review, it was learned that at least one engine in nuclear service had experienced loss of a stationary vane and bolting material originating from the rotating vane group. The net effect of this event was that no significant damage occurred, and the turbocharger performance was not effected. This is documented in NUREG 1216 as referenced. This issue resulted in PMs 1,2,5,6, and 7.

Results of Inspections

PM items 2,5, and 6 require teardown. Appendix B shows the number of times that e PM has been performed. The results of the inspections have shown that in most cases the modifications have resulted in eliminating significant bearing wear. In a case where some moderate amount of wear was found, this was detected via the oil monitoring trends. There is no case where failure occurred due to excessive bearing wear.

Since the original discovery of stationary vane failure and passing of this material through the rotating vane group, three other occurrences have occurred with the same result that the vane fragment passed through the rotating vane group with no significant damage and no significant degradation of turbocharger performance.

Conclusions

Based on the positive inspection results described and detailed in Appendix B, PM items 2,4,5,and 6 are not required. PMs 1,3 and 7 will be continued as a part of the future maintenance program. PMs along with results from the oil sampling program and exhaust temperature trending will show degradation in turbocharger performance and/or indicate increased bearing wear or vane damage. This will permit the utility to evaluate and take actions necessary to correct the problems. Should the turbochargers be removed from service for any reason, the PM recommendations 2,4,5, and 6 should be considered as good maintenance practice.

4.0 SYSTEM UNRELIABILITY

System unreliability for the TDI EDGs has been consistent with the industry median for the period since DR/QR was completed. A review of the INPO data for the period 7/89-6/92 gives a median unreliability for TDI EDGs as 0.0114. This average is well within the expectations of NRC guidance for either a plant needing a 0.0250 unreliability or 0.050 unreliability as directed by Station Blackout and equal to the current industry median. Some unreliability has been attributed to the engine teardowns and inspections. Industry experience indicates that elimination of frequent teardown and inspections has resulted in an additional decrease in unreliability. The following table lists the INPO data furnished for unreliability:

INPO UNRELIABILITY VALUE FOR TDI DIESELS

7/89-6/92

ENGINE	UNRELIABILITY
1	0.0556
2	0.0000
3	0.0238
4	0.0238
5	0.0357
6	0.0000
7	0.0000
8	0.0000
9	0.0112
10	0.0000
11	0.0371

12	0.0114
13	0.0373
14	0.0099
15	0.0000
16	0.0233
17	0.0360
18	0.0467
19	0.0059
20	0.0114
MEDIAN	0.0114

It is concluded from the data provided that the unreliability of the TDI EDGs is within the bounds and expectations of the regulatory guidance and other diesels within the nuclear industry.

5.0 SYSTEM UNAVAILABILITY

System unavailability has been reasonable for the TDI Enterprise engines since DR/QR as measured by the INPO indicators. (The INPO Indicators are based on unavailability during power operations.) The industry median (for all engines) is 0.0182. The median for the TDI engines is 0.0177. The following table gives the unavailability three year values for the TDI engines in service for the period 7/89-6/92:

INPO UNAVAILABILITY VALUES FOR TDI DIESELS

7/89-6/92

ENGINE	UNAVAILABILITY
1	0.0175
2	0.0117
3	0.0179
4	0.0464
5	0.0385
6	0.0156
7	0.0113
8	0.0127
9	0.0416
10	0.0323
11	0.0673
12	0.0411
13	0.0439

14	0.0142
15	0.0040
16	0.0051
17	0.0413
18	0.0152
19	0.0182
20	0.0167
MEDIAN	0.0177

Recent industry events have focused more attention on unavailability of safety related systems especially the diesels during modes of operation other than full power operation. The above numbers reflect standard industry practice of determining unavailability during periods of power and non power operation. Review of data from utilities involved with this submittal, accounting for unavailability during outages would substantially increase the median. As an example, assume an outage of 6 weeks for an overhaul on a diesel. This would result in 1008 hours out of service and if this were translated, would result in an unavailability of 11.5% for the year without any other unavailability factored in. In review of data from utilities supporting this licensing request, unavailability numbers in the range of 10-15% would not be uncommon with outage out of service time figured in. By not performing major teardowns, out of service durations during outages could be shortened to two weeks and significantly reduce this unavailability.

The basis of the TDI surveillance matrix deals with preventative maintenance, monitoring, and inspections. The latter of this list is by far the largest contributor to the significant out of service times experienced in outages. In addition the requirement to perform an overhaul every 10 years (a complete overhaul has not yet been performed after 10 years of operation) will add even more to the unavailability of the engines during outages. The overhaul frequency is discussed in detail in Section 3.1. This submittal addresses a solution to reduce unavailability by reducing engine teardowns and inspections. This will be accomplished by more closely monitoring and trending the data that is already being collected. Teardown and inspection will be performed when indicated by the maintenance/monitoring and trending programs for the engines.

Acceptance of this submittal will reduce unavailability and will comply with Station Blackout levels of unreliability which will reduce the risk of core melt as noted in work that has been performed on Station Blackout Issues. Acceptance will also help these utilities prepare for the issues to be addressed by the Maintenance Rule.

THE TRANSAMERICA DELAVAL, INC. OWNERS GROUP
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TDI OWNERS GROUP

GENERIC MAINTENANCE AND SURVEILLANCE PROGRAM

APPENDIX - II

I INTRODUCTION

The purpose of this appendix is to provide the TDI Owners with a set of maintenance and surveillance recommendations for diesel generator components which have been developed by TDI and/or the Owners Group as a result of the overall Owners Group Program and including subsequent testing and inspections performed following the review conducted by the original program. This appendix is intended to enhance the existing TDI Instruction Manual, Volume I and Volume III, which will maintain the qualification of the diesel generators for the life of the plant.

II METHODOLOGY

During the implementation of the Owners Group Program Plan, the Owners Group Technical Staff reviewed many sources of information regarding the maintenance and surveillance for the diesel generator components identified in this appendix. These sources included TDI Instruction Manuals, Service Information Memos (SIMs), and TDI correspondence on specific components. The basis of this matrix is formed by the following:

- Owners Group Technical Staff review of TDI Instruction Manuals, SIMs, and TDI correspondence on specific components.
- Technical Staff input regarding the adequacy of recommendations found in sources mentioned above.
- Additional maintenance recommendations identified during the DR/QR review and from 10CFR21 reports and operating experience at nuclear plants.
- Results of subsequent testing and surveillance (i.e., Shoreham EDG103 750-hour endurance run and subsequent engine teardown) performed following the review conducted during the original program.
- Additional review by the Owners Group representatives.

It should be noted that this revision in some cases modifies the original program results based on this additional information and review.

III RESULTS AND CONCLUSIONS

Proper maintenance is important in ensuring long, reliable and satisfactory service of the emergency diesel generators. Maintenance work, in order to be effective, must be carried out thoroughly and regularly. It is for these reasons that a detailed schedule of maintenance service has been laid out by the Owners Group for the TDI Diesel Generators. This schedule should be followed as closely as the operating conditions will permit. This maintenance service as specified supersedes previous general maintenance requirements, but is separate and does not supersede Quality Revalidation and/or modifications previously recommended. The schedule details specific components requiring maintenance on a regular basis. This schedule separates the maintenance activities into frequencies as set forth in the subsequently list of definitions.

Inspections, as outlined in this maintenance schedule, are to be performed and parts refurbished or replaced as required by the program or deemed necessary by the inspection. Any adverse findings shall be investigated and corrective action, including amended inspection frequencies, shall be implemented unless sufficient justification is present to do otherwise.

This generic matrix, Parts A, B, C together with Part D entitled "Site-Specific Maintenance Matrix" and the sources defined in Section II form the TDI Maintenance Program. Note that component numbers used in the generic matrix are for Texas Utilities' Comanche Peak Steam Electric Station - Unit 1. Part E provides a cross reference to identify corresponding components for other engines. Also note that a blank in the cross reference signifies that a component is not on a particular engine and thus that Owner would not perform that maintenance item.

Tables 1 and 2 of Part A provide engine operating and standby surveillance parameters and frequencies. It is recommended that the utility address these tables in its operating and monitoring programs. Table 1 addresses operating parameters and is not duplicated in the maintenance schedules; these parameters are to be recorded and/or checked during the monthly testing and any other period of operation. Table 2 addresses the standby parameters that occur on a daily frequency and are not duplicated in the maintenance schedules.

IV. DEFINITION OF TERMS

1. Overhaul Frequency

a) A complete engine teardown inspection will be performed every 10 years. The utility has the flexibility to inspect one engine/reactor unit at the EOC prior to 10 years and the other engine at the EOC following 10 years. Alternately for PWR units, the inspection may be performed coincident with the 10-year reactor vessel inservice inspection. This will permit both engines for each unit to be disassembled in parallel since one engine will not have to remain in service with the reactor vessel off loaded. (For reactor units having three engines, the inspections are to be carried out as above with the third engine to be inspected at the second EOC following 10 years). The 10-year interval will typically be taken from issuance of the Low Power Operating license or from subsequent teardown and inspection for plants already in operation.

b) A one time inspection will be performed at the EOC closest to five years. For a unit, one engine may be inspected at the EOC prior to five years and the other at the EOC after five years to minimize plant outage length. (For reactor units having three engines, the inspections are to be carried out as above with the third engine to be inspected at the second EOC following five years). This inspection will generally involve the same components as the 10-year teardown; however, only a sample of items for some components will be inspected as set forth in the maintenance schedule. During this five-year inspection, any significant adverse findings of a particular component will result in an inspection of all such components of that engine to determine any adverse trends. Favorable findings will result in reassembly of the engine for service.

2. Daily Frequency - To be performed once per day.

3. Monthly Frequency - To be performed once in a month; normally during, before, or after test run per plant Technical Specifications.

4. EOC - (End of Cycle) - To be performed once during outage for refueling.

5. Alternate EOC - To be performed once every other outage for refueling.

6. Five Years - To be performed once at the EOC occurring nearest to the end of a recurring five-year period or at the EOC midway between the one time EOC 2 inspections and the first overhaul inspection and subsequently midway between each overhaul.

7. As Required - To be performed as often as good maintenance, site procedures, manufacturer's recommendations, or experience dictate as determined by site personnel.

8. Maintenance - Monitoring and/or surveillance on a periodic frequency to assure the component will perform its intended function in a safe reliable manner.

9. Accessible - Any item on which the required function can be performed without disassembly of an engine component. Removal of defined access cover is <u>not</u> considered disassembly.

10. Appropriate NDE - Nondestructive examination selected by site personnel that is most suitable to obtain the information sought by an individual inspection item; choice of NDE shall be made to assure that the technique will detect indications consistent with the acceptance criteria.

TABLE 1

Diesel Engine Operating Surveillance Parameters and Frequency

Component		Frequency
1)	Lube Oil Inlet Pressure to Engine	Log hourly
2)	Lube Oil Filter Differential Pressure	Log hourly
3)	Lube Oil Temperature (engine inlet and outlet)	Log hourly
4)	Lube Oil Sump Level	Log hourly
5)	Turbocharger Oil Pressure	Log hourly
6)	Fuel Oil Filter Differential Pressure	Log hourly
7)	Fuel Oil to Engine Pressure	Log hourly
8)	Fuel Oil Day Tank Level	Check hourly
9)	Jacket Water Pressure (engine inlet)	Log hourly
10)	Jacket Water Temperature (in, out)	Log hourly
11)	Engine Cylinder Temperature Exhaust - All (If temperature in any one cylinder exceeds 1050°, refer to MP-022/023 Item 7.)	Log hourly
12)	Manifold Air Temperature (RB, LB for DSRV Engines)	Log hourly
13)	Manifold Air Pressure (RB, LB for DSRV Engines)	Log hourly
14)	Starting Air Pressure (RB, LB for DSRV Engines)	Check hourly
15)	Crankcase Vacuum	Log hourly
16)	Engine Speed	Log hourly
17)	Hour Meter	Log hourly
18)	Kilowatt Load	Log hourly
19)	Visual Inspection for Leaks, etc.	Check hourly

TABLE 2

Diesel Engine Standby Surveillance Parameters and Frequency

Component	Frequency
1) Lube Oil Temperature (in, out)	Log daily
2) Lube Oil Sump Level	Log daily
3) Check Operation of Lube Oil Keep-warm Pump Motor	Daily
4) Monitor Lube Oil Keep-Warm Strainer and/or Filter Differential Pressure	Daily
5) Perform a visual inspection for leakage of the Lube Oil Heat Exchanger. Verify that no leakage through the leak-off ports of the lantern ring is present.	Daily
6) Fuel Oil Day Tank Level	Log daily
7) Jacket Water Temperature (in, out)	Log daily
8) Perform a visual inspection for leakage at packing for Jacket Water Heat Exchanger whenever the engine is in the emergency STANDBY mode. Verify that no leakage through the leak-off ports of the lantern ring is present.	Daily
9) Verify proper governor oil level	Daily
10) Verify proper oil level of generator pedestal bearing	Daily
11) Starting Air Pressure	Log daily
12) Drain air receiver float traps and/or drain Starting Air Storage Tank and monitor the quantity of moisture produced. If quantity of moisture is excessive, correct immediately.	Daily
13) Check Operation of Compressor Air Traps	Daily

TABLE 2 (Cont'd)

Diesel Engine Standby Surveillance Parameters and Frequency

Component	Frequency
14) Test Annunciators	Before Engine Operation
15) Check Alarm Clear	Before Engine Operation
16) Inspect for Leaks	Daily
17) Visually inspect intercooler for external leaks including intake manifold drain connection.	Daily

APPENDIX A

PART B

TDI
OWNERS GROUP

APPENDIX - II

GENERIC MAINTENANCE MATRIX

PART B

PHASE I COMPONENTS

GENERIC MAINTENANCE MATRIX - PHASE I

Component Number	Component Identification	PM Recommendation	Monthly	EOC	Alt EOC	5 Year	Overhaul	Comments
MP-022/23	Turbocharger	1. Measure vibration and check with baseline data.		X				To be accomplished after obtaining stable exhaust temperature conditions.
		2. Inspect impeller/diffuser and clean if necessary.				X		
		3. Measure rotor end play (axial clearance) to identify trends of increasing clearance (i.e., thrust bearing degradation).		X				Review thrust bearing axial clearances after inspection to determine if a trend exists. Any trend toward increasing axial clearance could signify thrust bearing degradation.
		4. Perform visual and blue check inspections of the thrust bearing.				X		Note: Thrust bearing inspection should also be performed after experiencing each 40 nonprelubed (automatic) fast starts. In addition, a one-time inspection should be completed after the first 100 engine starts.
		5. Disassemble, inspect, and refurbish.				X		Note: During reassembly, ensure that capscrews are properly installed with the recommended torque. If QR inspection was performed prior to accumulating significant hours (i.e., the number of hours accumulated during plant preoperational testing, approximately 100 hours), the turbochargers should be reinspected at the next EOC.
		6. The nozzle ring components and inlet guide vanes should be visually inspected for missing parts or parts showing distress. If such conditions are				X		Or perform a visual inspection on one turbocharger per nuclear unit at each EOC.

Component Number	Component Identification	PM Recommendation	Monthly	EOC	Alt EOC	5 Year	Overhaul	Comments
		noted, the entire ring assembly should be replaced.						Any turbocharger in which nozzle ring anomalies are found is to be reinspected at the next EOC. Note: Discontinue inspection with appropriate redesign.
		7. Monitor inlet temperature to ensure gas temperature does not exceed manufacturer's recommendation of 1200°F if exhaust temperature for any cylinder exceeds 1050°F (Refr: Table 1).						Monitoring may be performed using permanent in-line thermocouple, strap-on thermocouple, heat gun, or other suitable means that has been appropriately tested and calibrated per plant procedures. Note: Also perform monitoring any time the engine operates in an unbalanced condition.
02-305A	Base Assembly	1. Perform a visual inspection of the base. The inspection should include the areas adjacent to the nut pockets of each bearing saddle and be conducted after a thorough wipe down of the surfaces, using good lighting.					X	Note: Any cracks detected must be investigated further before the engine is allowed to return to service. The mating surfaces of the base and cap shall be thoroughly cleaned with solvent before any reassembly. Perform on EOC basis for 3 cycles, then overhaul provided there are satisfactory results. Note: 3 EOC inspections may be eliminated by performing a metal analysis to confirm consistent to class 40 grey iron requirements; performing analysis does not eliminate need for overhaul inspections.

GENERIC MAINTENANCE MATRIX - PHASE I

Component Number	Component Identification	PM Recommendation	Monthly	EOC	Alt EOC	5 Year	Overhaul	Comments
02- .5C	Main Bearing Caps - Studs and Nuts	1. The mating surfaces at the bearing cap/saddle interface should be inspected when disassembled to ensure the absence of surface imperfections that might prevent tight boltup. Note: Upon removal of bearing caps, clean mating surfaces with a solvent prior to reassembly of the caps to the base.						
02-310A	Crankshaft	See site specific recommendations						
02-315A	Cylinder Block	See site specific recommendations						
02-315C	Cylinder Liners	1. Perform a visual inspection of liners for progressive wear.						To be performed for one EOC following piston removal; then discontinue until next piston removal. Boroscopic inspection is acceptable if heads are not removed. Complete TDI Inspection and Maintenance Record Form No. 315-1-1 as applicable. TDI Instruction Manual, Volume 1, Section 6.
02-340A/B	Connecting Rods, Bushings and Bearing Shells (Generic)	1. Inspect and measure all connecting rod bearing shells to verify lube oil maintenance, which affects wear rate.					X	Complete TDI Inspection and Maintenance Record Form No. 340-1-1 as applicable. TDI Instruction Manual, Volume 1, Section 6, appendix III for clearance values. Perform inspection at 5 years, on items accessible, consistent with item 2 of this component.

Component Number	Component Identification	PM Recommendation	Monthly	EOC	Alt EOC	5 Year	Overhaul	Comments
		2. Inspect and measure the connecting rods. Note: Perform inspection and measure four connecting rods for DSRVs and two for DSRs at random at one time 5-year inspection.					X	Complete TDI Inspection Maintenance Record Form No. 340-2-1, -2 as applicable, TDI Instruction Manual, Volume I, Section 6.
		3. Perform an X-ray examination on all replacement bearing shells to acceptance criteria developed by Owners Group Technical Staff.						This is to be performed prior to installation of any replacement bearing shells as required.
		4. All connecting rod bolts, nuts, and washers should be visually inspected, and damaged parts should be replaced. The bolts should be MT inspected to verify the continued absence of cracking. No detectable cracks should be allowed at the root of the threads.					X	Perform inspection at 5 years, on items accessible, consistent with Item 2 of this component.
		5. During any disassembly that exposes the inside diameter of a rod-eye (piston pin) bushing, the surface of the bushing should be LP inspected to verify the continued absence of linear indications in the heavily loaded zone width +/-15 degrees of the bottom dead-center position.						Perform inspection, as required and on items accessible, consistent with Item 2 of this component.
02-340 A/B DSRV's only	Connecting Rods, Bushings and Bearing Shells	6. Measure the clearance between the link pin and link rod. This clearance should be zero; i.e.,						To be performed at each reassembly of link pin to link rod.

GENERIC MAINTENANCE MATRIX - PHASE I

Component Number	Component Identification	PM Recommendation	Monthly	EOC	Alt EOC	5 Year	Overhaul	Comments
		no measurable clearance when the specified bolt torque of 1,050 ft-lbs is applied.						
		7. At the overhaul, visually inspect the rack teeth surfaces for signs of fretting and at one time 5-year inspection for rods disassembled.					X	
		8. Inspect mating surfaces to verify that the minimum manufacturers' recommended percent contact surface is available.						To be performed once for new and/or replacement parts.
		9. If connecting rod bolt stretch was measured ultrasonically during reassembly following the preservice inspection, the lengths of the two pair of bolts above the crankpin should be remeasured ultrasonically before the link rod box is disassembled. If ultrasonic measurement was not previously used, begin use at next inspection that accesses the connecting rods. Measure bolt stretch before disassembly.					X	Also to be performed at any time the connecting rod is disassembled. Perform inspection at 5 years, on items accessible, consistent with Item 2 of this component.
		10. All connecting rod bolts should be visually inspected for thread damage (galling) and the two pairs of connecting rod bolts above the crankpin should be MT inspected to verify the absence of cracking. All washers used with the bolts should be examined visually for signs of galling or cracking and replaced if damaged. If prestressor package is installed, this item does <u>not</u> apply.					X	Also to be performed at any time the connecting rod is disassembled. Perform inspection at 5 years, on items accessible, consistent with Item 2 of this component.

GENERIC MAINTENANCE MATRIX - PHASE I

Component Number	Component Identification	PM Recommendation	Monthly	EOC	Alt EOC	5 Year	Overhaul	Comments
		11. A visual inspection should be performed of all external surfaces of the link rod box to verify the absence of any signs of service-induced distress					X	Also to be performed at any time the connecting rod is disassembled. Perform inspection at 5 years, on items accessible, consistent with Item 2 of this component.
		12. All of the bolt holes in the link rod box should be inspected for thread damage (galling) or other signs of abnormalities. Bolt holes subject to the highest stresses (the pair immediately above the crankpin) should be examined with an appropriate non-destructive method to verify the absence of cracking. Any indications should be recorded for evaluation and corrective action. If prestressor package is installed, this item does <u>not</u> apply.					X	Also to be performed at any time the connecting rod is disassembled. Perform inspection at 5 years, on items accessible, consistent with Item 2 of this component
02-341A	Pistons	1. Inspect and measure skirt and piston pin. This item assumes that AE skirts are installed. For other types, see site-specific recommendations.					X	Complete TDI Inspection and Maintenance Report Form No 341-1-1 as applicable, TDI Instruction Manual, Volume 1, Section 6. Use Volume 1, Section 8, Appendix III for clearances values. To be performed at 5-year interval on sampling basis consistent with Component 02-340A/B-Connecting Rods.
02-360A	Cylinder Head	1. Visually inspect cylinder heads (all cylinders).					X	Complete TDI Inspection and Maintenance Record Form No. 360-1-1 as applicable, TDI Instruction Manual, Volume 1, Section 6 - one sheet for each head. To be performed at 5-year interval on sampling basis consistent with Component 02-340 A/B - Connecting Rods.

Component Number	Component Identification	PM Recommendation	Monthly	EOC	Alt EOC	5 Year	Overhaul	Comments
		2. Record cold compression pressures and maximum firing pressures.		X				If so indicated - remove cylinder heads, grind valves, and reseat. Refr TDI Instruction Manual, Volume I, Section 6.
		3. Blow-over the engine at least 4 hours but not more than 8 hours after engine shutdown. The cylinder cocks should be open for detection of water leakage into the cylinders. A second air roll should be performed in the same manner approximately 24 hours after engine shutdown. In addition, the engine should be air rolled shortly before any planned start.						In the event water is detected, the cylinder head should be replaced or returned to the vendor for repair. Delete post-run air roll requirements for engines with Group III heads after one cycle with positive inspection results.
		4. Visually inspect the area around the fuel injection port on each cylinder head during the normal monthly run for signs of leakage.	X					If water leakage is detected, the head(s) should be replaced.
02-365C	Fuel Injection Tubing	1. Check tubing for leaks at compression fittings.	X					All fuel oil leak inspections to be performed while the engine is running or whenever the compression fittings have been disturbed.
		2. Visually inspect tubing lengths for fuel oil leaks or cracks if tubing is unshrouded. If shrouded, fuel oil leakage can be detected at the leak-off ports in the base nuts, which are provided for this purpose, or by annunciator if so equipped.	X					Fitting inspection for leaks to be performed at engine operation following shutdown. Subsequent inspections to be performed periodically as indicated. Unshrouded tubing, used as replacement, should be fully inspected consistent with FaAA NDE Procedure 11.10 prior to bending.

GENERIC MAINTENANCE MATRIX - PHASE I

Component Number	Component Identification	PM Recommendation	Monthly	EOC	Alt EOC	5 Year	Overhaul	Comments
02-390C	Push Rods	1. Each push rod of the forged-head design should be inspected by liquid penetrant prior to installation or, if installed, at each overhaul. This should be repeated, until it has been determined by 750 hours of operation at the load level used for surveillance testing that the push rod will not develop service-induced cracks. Push rods confirmed in this way need be examined only visually at subsequent overhauls. Push rods of the forged-head design exhibiting cracks larger than 0.25 inch should be replaced, preferably with push rods of the friction-welded design. Each forged-head rod should also be visually inspected one time to confirm that the head was fully inserted in the tube prior to welding.					X	Refr: PNL-5600
		2. Each push rod of the friction-welded design should be inspected initially by liquid penetrant. If this initial inspection was not performed prior to placing the push rods in service, it should be performed at the first overhaul. If the friction-welded push rod has been previously inspected by liquid penetrant, then visual examination will suffice for future inspections. All friction-welded push rods with cracks should be replaced, preferably with push rods of the same design.					X	Refr: PNL-5600. If initial inspection was not performed, perform on sampling basis at 5-year inspection consistent with Component 340A/B - Connecting Rods.

GENERIC MAINTENANCE MATRIX - PHASE I

Component Number	Component Identification	PM Recommendation	Monthly	EOC	Alt EOC	5 Year	Overhaul	Comments
02-390G	Rocker Arm Capscrews, Drive Studs (Pop Rivets)	1. Verify capscrew torque values during QR inspections. If not performed at QR, verify at next EOC, then as required at reassembly.						Use TDI Instruction Manual, Volume I, Section 8, Appendix IV for proper torque values.
		2. Verify that rocker arm drive studs are intact and tight during QR inspection or EOC1, then as required at reassembly.						
02-425A	Jacket Water Pump - Gear	1. Visually inspect jacket water pump gear for chipped or broken teeth, excessive wear, pitting or other abnormal conditions.				X		Any abnormal situations or indications of progressive pitting should be reported for an engineering evaluation. For engines with less than 750 hours, also inspect by EOC2.
		2. Check the key to keyway interface for a tight fit on both the pump shaft to impeller and the spline to pump shaft during pump reassembly. At next disassembly, verify impeller is one piece (i.e., without a bore insert). If it is not a one-piece impeller, replace.					X	This along with the drive fit of the impeller onto the shaft will preclude past problems where relative motion between shaft and impeller caused fretting and upset of the keyway sides.
		3. It is recommended that the castle nut that drives the external spline on its taper have minimum and maximum torque values of 120 ft-lbs and 660 ft-lbs, respectively for DSRVs and a maximum torque value of 77 ft-lbs for DSRs.						Torque valves will be checked each time castle nut is reassembled.

SITE-SPECIFIC MAINTENANCE MATRIX

Component Number	Component Identification	PM Recommendation	Monthly	EOC	Alt EOC	5 Year	Overhaul	Comments
02-310A	Crankshaft	1. Measure and record crankshaft web deflections (hot and cold).		X				Complete TDI Inspection and Maintenance Record Form No. 310-1-1 as applicable. TDI Instruction Manual, Volume 1, Section 6. Refr: TDI Instruction Manual, Volume 1, Maintenance Schedule.
		2. Examine the fillets and oil holes of three main bearing journals (4, 6, & 8) using LP. If indications are evident, a more thorough examination should be made using appropriate NDE methods.					X	Also to be performed once at 5 years. Refr: PNL-5600.
		3. Examine the fillets and oil holes in three of the crankpin journals (choose 3 from Nos. 3 through 8 inclusive) using LP. If indications are evident, a more thorough examination should be made using appropriate NDE methods.					X	Also to be performed once at 5 years. Refr: PNL-5600.
		4. Measure diameter of crankpin journals.					X	Complete TDI Inspection and Maintenance Record Form No. 310-3-1 as applicable. TDI Instruction Manual, Volume 1, Section 6. Aso perform inspection at 5 years, on items accessible, consistent with this component and Component 02-340A/B.
		5. Analyze the trends of cylinder pressure and temperature measurements to detect imbalances.		X				If an engine operates in a <u>severely</u> unbalanced condition, reinspect the oil holes for fatigue cracks within a time-frame determined by the utility considering the particular circumstances of the abnormal operation. Refr: PNL-5600.

SITE-SPECIFIC MAINTENANCE MATRIX

Component Number	Component Identification	PM Recommendation	Monthly	EOC	Alt EOC	5 Year	Overhaul	Comments
		Note: To avoid the effect of the 4th order resonance, steady normal-loaded operation at speeds more than a few rpm below the rated speed of 450 rpm should be avoided. Appropriate precautions should be taken to prevent sustained engine operation with significant cylinder imbalance. Lower speeds for testing and break-in are permissible. Avoid resonance frequencies.						Ref: FS-5600.

SITE-SPECIFIC MAINTENANCE MATRIX

Component Number	Component Identification	PM Recommendation	Monthly	EOC	Alt EOC	5 Year	Overhaul	Comments
02-315A	Cylinder Block	1. Perform inspections per DR/QR Report 02-315A.						Inspections based on cumulative engine hours in conjunction with FaAA reports FaAA-84-9-11 and SP-84-6-12(j).
		2. Perform visual inspection for cracks. Note: Visual inspection not required if an appropriate NDE is performed.					X	

DUKE ENGINEERING
& SERVICES, INC.

230 South Tryon St
P.O. Box 1004
Charlotte NC 28201-1004

Bus (704) 373-2473
Fax (704) 373-2696

December 8, 1992

Document Control Desk
Nuclear Regulatory Commission
Washington, DC 20555

Subject: TDI Owners Group
Generic Licensing Submittal for Emergency Diesel Generators
Conditions of License for Utilities with Enterprise Engines

Gentlemen:

Attached please find five (5) copies of the subject submittal. This submittal is made on behalf of eight utilities having Enterprise Emergency Diesel Generators (EDG) for emergency standby AC power. These utilities are listed below with the respective plants they operate:

UTILITY	STATION
Texas Utilities, Inc	Comanche Peak
Entergy Operations, Inc.	Grand Gulf
Duke Power Co., Inc.	Catawba
Carolina Power and Light Co., Inc.	Shearon Harris
Georgia Power/Southern Nuclear Operating, Inc.	Vogtle
Cleveland Electric Illuminating, Inc./Centerior, Inc.	Perry
Gulf States Utilities, Inc.	River Bend
Tennessee Valley Authority	Bellefonte

This Owners Group was formed in late 1983 following the crankshaft failure of an Enterprise EDG at the Shoreham Nuclear Plant. A complete Design Review and Quality Review of these EDGs was performed and completed in February 1985. The Nuclear Regulatory Commission reviewed the detailed Owners Group Program Plan and the components referred to as Phase I. (This Phase I program reviewed 16 major components that were selected as being the most critical to engine operation.) Phase II was completed by the Owners Group but was not reviewed in detail by the NRC staff as they had concluded that review of the Program Plan and Phase I of that plan provided sufficient justification for operation of the engines in a safe and reliable manner.

The NRC review of Phase I is documented in NUREG 1216. This document also imposed some of the findings of the review as conditions of license. It was noted in these findings that many of these conditions were imposed due to the lack of operational experience with these machines in nuclear standby service. Since 1985, over 9000 hours of operation have been logged collectively by TDI engines. While a few problems have been found, the program has served its function and has increased the reliability of these machines. In addition, many of the survelliance items that are in place have proven to be as effective as inspection for revealing a potential problem. Using surveillances in lieu of inspections will also contribute to decreased unavailability especially during outages.

This submittal presents background on the relevant issues for the Phase I components and the history collected over the past seven years of performing teardowns and inspections required by NUREG 1216. The conclusions drawn from this data are also presented. It is respectfully requested that the staff review this information by June 30, 1993, and permit the utilities listed above to remove these prescriptive teardowns and inspections as licensing conditions to give the utility the flexibility to determine the best way to monitor engine condition while maintaining reliability and reducing unavailability.

Correspondence concerning this issue should be addressed to C. W. Hendrix or R. C. Day.

Sincerely,

J B George
Chairperson
TDI Owners Group

RCDay
for CW Hendrix
Project Manager
Duke Engineering and Services, Inc.

RCD/pja.017

Attachment

APPENDIX B

APPENDIX B

RESULTS OF INSPECTION FOR TDI DIESEL GENERATOR PHASE I COMPONENTS

COMPONENT NAME	COMPONENT NO.	PM RECOMMENDATION NO.	NO. OF INSPECTIONS	RESULTS AND COMMENTS
TURBOCHARGER	MP 022/023	1	Note 1	No problems found.
		2	50	No problems found.
		3	87	No problems found.
		4	47	Bearing wear has been reported. This wear has been dispositioned by the vendor as being within acceptable limits.
		5	47	No problems found.
		6	60	Vogtle and Grand Gulf have reported broken or missing bolts passing through the rotating element without identifiable degradation. Vogtle, Grand Gulf and Catawba have reported missing stationary vanes without identifiable degradation. Missing or damaged items were replaced.
		7	Note 2	Performed on each test run.

Note 1: Inspections performed monthly. The number of inspections are greater than 200.

Note 2: Performed on multiple occassions during test runs. A large data base exists.

Reference Attachment 1 for Phase I Components

11/30/92

APPENDIX B

RESULTS OF INSPECTION FOR TDI
DIESEL GENERATOR PHASE I COMPONENTS

COMPONENT NAME	COMPONENT NO.	PM RECOMMENDATION NO.	NO. OF INSPECTIONS	RESULTS AND COMMENTS
BASE ASSEMBLY	02-305A	1	43	No problems found.
Reference Attachment 1 for Phase I Components				11/30/92

APPENDIX B

RESULTS OF INSPECTION FOR TDI DIESEL GENERATOR PHASE I COMPONENTS

COMPONENT NAME	COMPONENT NO.	PM RECOMMENDATION NO.	NO. OF INSPECTIONS	RESULTS AND COMMENTS
MAIN BEARING CAPS - STUDS AND NUTS	02-305C	1	28	Inspections are based upon the number of bearing caps examined. Perry has reported one shell with rolled edges due to contact with counter weight. Bearing performance was determined to be satisfactory and the reported item corrected.

Reference Attachment 1 for Phase I Components 11/30/92

APPENDIX B

RESULTS OF INSPECTION FOR TDI DIESEL GENERATOR PHASE I COMPONENTS

COMPONENT NAME	COMPONENT NO.	PM RECOMMENDATION NO.	NO. OF INSPECTIONS	RESULTS AND COMMENTS
CRANKSHAFT	02-310A	1	188	No problems found. Inspection is number of hot and cold deflection measurements taken.
		2	67	Inspection is number of oil holes inspected. Upon bearing rollout to perform inspections, River Bend has experienced minor cavitation, including pitting on bearing surfaces. This was evaluated and dispositioned as not a problem. The bearings in question had performed their function and could continue to operate withouy adverse effects. Bearings were replaced as good engineering practice.
		3	42	No problems found. Inspection is number of fillet and oil holes inspected.
		4	35	No problems found. Inspection is number of crackpin journals measured.
		5	Note 1	No problems found.

Note 1: Inspections performed monthly. The number of inspections are greater than 200.

Reference Attachment 1 for Phase I Components

11/30/92

APPENDIX B

RESULTS OF INSPECTION FOR TDI
DIESEL GENERATOR PHASE I COMPONENTS

COMPONENT NAME	COMPONENT NO.	PM RECOMMENDATION NO.	NO. OF INSPECTIONS	RESULTS AND COMMENTS
CYLINDER BLOCK	02-315A	1	105	No problems found. Inspection is related to number of areas
				inspected under individual heads when removed.
		2	159	No problems found. Number of inspections include
				inspections made by several utilities during operation.

Reference Attachment 1 for Phase I Components

APPENDIX B

RESULTS OF INSPECTION FOR TDI DIESEL GENERATOR PHASE I COMPONENTS

COMPONENT NAME	COMPONENT NO.	PM RECOMMENDATION NO.	NO. OF INSPECTIONS	RESULTS AND COMMENTS
CYLINDER LINERS	02-315C		512	Number of inspections represent number of liners inspected. Vogtle has reported light and moderate scratches with bright spots and carbon build-up. This has been evaluated and dispositioned as acceptable. Grand Gulf has found indications of porosity. The liners performed as designed and were dispositioned as acceptable, but were replaced as good engineering practice.
Reference Attachment 1 for Phase I Components				11/30/92

APPENDIX B

RESULTS OF INSPECTION FOR TDI DIESEL GENERATOR PHASE I COMPONENTS

COMPONENT NAME	COMPONENT NO.	PM RECOMMENDATION NO.	NO. OF INSPECTIONS	RESULTS AND COMMENTS
CONNECTING RODS, BUSHINGS AND BEARING SHELLS (GENERIC)	02-340A/B	1	42	Inspections indicate the number of connecting rod bearings. River Bend has reported some cavatiation induced pitting. The bearings remained capable of performing as designed, but were replaced as good engineering practice. The oil analysis did identify bearing material in the lube oil prior to replacement.
				Vogtle has found three shells with evident wear and/or indications. These shells were evaluated and dispositioned as acceptable. They were replaced as good engineering judgement.
		2	36	No problems found. Inspection is the number of connecting rods examined.
		3	NA	See Referenced submittal to NRC, Attachment (?)
		4	89	No problems found. Inspection is the number of connecting rods examined.
		5	34	No problems found. Inspection is the number of rod-eye bushings examined.
		6	71	No problems found. Inspection is the number of connecting rods examined.
Reference Attachment 1 for Phase I Components				11/30/92

APPENDIX B

RESULTS OF INSPECTION FOR TDI DIESEL GENERATOR PHASE I COMPONENTS

COMPONENT NAME	COMPONENT NO.	PM RECOMMENDATION NO.	NO. OF INSPECTIONS	RESULTS AND COMMENTS
CONNECTING RODS, BUSHINGS AND BEARING SHELLS (GENERIC)	02-340A/B	7	20	No problems found. Inspection is the number of rack teeth examined.
		8	73	No problems found. Inspection is the number of sets of rod teeth examined (required for new or replacement rods).
		9	296	No problems found. Inspection is the number of connecting rods examined.
		10	20	Inspection is the number of connecting rods examined. Vogtle found 1 stud bolt missing. This was evaluated and dispositioned as acceptable. No additional problems found.
		11	20	
		12	20	Inspection is the number of connecting rods examined. Vogtle has found 1 indication in a hole. It was evaluated and dispositioned as acceptable. The rod was replaced as good engineering practice.
Reference Attachment 1 for Phase I Components				11/30/92

APPENDIX B

RESULTS OF INSPECTION FOR TDI DIESEL GENERATOR PHASE I COMPONENTS

COMPONENT NAME	COMPONENT NO.	PM RECOMMENDATION NO.	NO. OF INSPECTIONS	RESULTS AND COMMENTS
PISTONS	02-341A	1	39	Inspection is the number of pistons examined. Grand Gulf has found 3 piston pins and plugs to be slightly loose. This was evaluated and dispositioned as acceptable. The plugs were replaced as good engineering practice.
Reference Attachment 1 for Phase I Components				11/30/92

APPENDIX B

RESULTS OF INSPECTION FOR TDI DIESEL GENERATOR PHASE I COMPONENTS

COMPONENT NAME	COMPONENT NO.	PM RECOMMENDATION NO.	NO. OF INSPECTIONS	RESULTS AND COMMENTS
CYLINDER HEAD	02-360A	1	151	Inspection is the number of heads examined. Vogtle has found minor pitting and nicks in 4 valves. This was evaluated and dispositioned as acceptable. Perry has found 2 exhaust valve seat cuts. Performance was not effected. This was evaluated and dispositioned as acceptable. The heads were replaced as good engineering practice. River Bend has found problems with swivel pads. This is discussed in Section 3.12
		2	Note 1	No problems found.
		3	Note 2	Mist has been detected on several ocassions, leading to a in-depth investigation as to the cause. The results are incorporated in Section 3.12 and PM Recommendation No. 1
		4	Note 3	Inspection performed each run. No problems found.
Note 1: Inspection performed each EOC and more frequently by several utilities. This inspection collectively amounts to greater than 200 inspections.				
Note 2: Inspection performed prior to each start and collectively amounts to greater than 200 inspections.				
Note 3: Inspections performed monthly. The number of inspections are greater than 200.				
Reference Attacnment 1 for Phase I Components				11/30/92

APPENDIX B

RESULTS OF INSPECTION FOR TDI
DIESEL GENERATOR PHASE I COMPONENTS

COMPONENT NAME	COMPONENT NO.	PM RECOMMENDATION NO.	NO. OF INSPECTIONS	RESULTS AND COMMENTS
FUEL INJECTION TUBING	02-365C	1	Note 1	Minor fitting leaks have been found and repairs are made as leaks are discovered. Catawba has examined 1 tubing failure of unshrouded tubing due to vibrations. River Bend has experienced 1 failure of the shrouded tubing due to the fuel injection pump base cap screws failing. The tubing was replaced and the engine restored to service.
		2	Note 1	Same as for PM Recommendation No. 1
Note 1: Inspections performed monthly. The number of inspections are greater than 200.				
Reference Attachment 1 for Phase I Components				11/30/92

APPENDIX B

RESULTS OF INSPECTION FOR TDI
DIESEL GENERATOR PHASE I COMPONENTS

COMPONENT NAME	COMPONENT NO.	PM RECOMMENDATION NO.	NO. OF INSPECTIONS	RESULTS AND COMMENTS
PUSH RODS	02-390C	1	NA	Push rods of this design are not in service.
		2	940	Inspection is the number of push rods examined. No problems found.
Reference Attachment 1 for Phase I Components				11/30/92

APPENDIX B

RESULTS OF INSPECTION FOR TDI DIESEL GENERATOR PHASE I COMPONENTS

COMPONENT NAME	COMPONENT NO.	PM RECOMMENDATION NO.	NO. OF INSPECTIONS	RESULTS AND COMMENTS
ROCKER ARM CAPSCREWS, DRIVE STUDS (POP RIVETS)	02-390G	1	551	Inspection is of rocker arm assemblies. No problems found.
		2	551	Inspection is for rocker arm assemblies. Two pop rivets have been found missing. One each on the River Bend EDGs. Result was no degradation in EDG operability since oil flow continued to the required locations. Grand Gulf has found bearing wear. An evaluation has dispositioned this as normal.
Reference Attachment 1 for Phase I Components				11/30/92

APPENDIX B

RESULTS OF INSPECTION FOR TDI
DIESEL GENERATOR PHASE I COMPONENTS

COMPONENT NAME	COMPONENT NO.	PM RECOMMENDATION NO.	NO. OF INSPECTIONS	RESULTS AND COMMENTS
JACKET WATER PUMP - GEAR	02-425A	1	22	Inspection is for jacket water pump drive gears. Vogtle has found gears with minor pitting. Grand Gulf has found gears with excessive wear. Vendor has a proposed modification to allow easy removal of pump for inspection. They are also evaluating the gear design.
		2	8	Inspections are for the number of verifications. No problems found.
		3	1	Inspections are for the number of verifications. No problems found.
Reference Attachment 1 for Phase I Components				11/30/92

APPENDIX C

DUKE ENGINEERING
& SERVICES, INC.

230 South Tryon St.
P.O. Box 1004
Charlotte, NC 28201-1004

Bus (704) 373-247
Fax (704) 373-269

October 31, 1991

Mr. P. Om Chopra
Office of Nuclear Reactor Regulation
Electrical Systems Branch (MS 7 E4)
U. S. Nuclear Regulatory Commission
Washington, DC 20555

Re: Cooper-Enterprise Clearinghouse Group
Diesel Generators
Position Paper on Radiograph Requirements
for Connecting Rod Bearing Shells
File: MTS-4086

Dear Mr. Chopra:

Enclosed is Cooper-Enterprise Clearinghouse Group's position concerning the current radiographic examination requirement for the diesel generator's connecting rod bearing shells as detailed in Appendix II of the Design Review/Qualification Revalidation (DR/QR) Report. The position paper provides the necessary technical justification to permit elimination of requirements to inspect replacement bearings shells by radiographic techniques.

The Clearinghouse Group is requesting relief from the radiographic examination requirements because the bearings supplied by Cooper Industries are presently being manufactured by Federal-Mogul, rather than the former manufacturer/supplier, ALCOA. Federal-Mogul manufactures their bearing using a centrifuge process,a more advanced method than the static mold process used by ALCOA. The centrifuge process eliminates the potential for void formation and therefore radiographic examination is not required.

The Clearinghouse Group requests you review the enclosed document and based upon the technical justification provided, determine on a generic basis, that the current radiographic requirements are not necessary.

Response to this issue by January 31, 1992 will be greatly appreciated by the Clearinghouse and the individual utilities members. Should you have questions, please direct them to Rick Deese at (704) 875-4065.

Very truly yours,

RD Broome

R. D. Broome
Project Manager
Cooper-Enterprise Clearinghouse
Duke Engineering & Services, Inc.

J. B. George
Chairperson
Cooper-Enterprise Clearinghouse
TU Electric

RDB/VMA/100991

Enclosure

cc: E. B. Tomlisc NRC)
Clearinghouse Representatives
R. J. Deese

POSITION PAPER FOR RADIOGRAPHIC EXAMINATION OF CONNECTING ROD BEARING SHELLS (02-340B) FOR ENTERPRISE DSR-8, DSRV-16 AND DSRV-20 ENGINES

Purpose

The purpose of this position paper is to provide sufficient technical justification to permit the elimination of the DR/QR Appendix II requirement to inspect replacement bearing shells by radiographic techniques.

Background

During the period of 1983-1985, thirteen utilities formed the TDI Owners Group and contracted Duke Management and Technical Services, Inc. (now Duke Engineering & Services, Inc.) to perform a Design Review and Quality Revalidation (DR/QR) of the TDI engines following the crankshaft failure at Shoreham. A portion of this review focused on the connecting rod bearing shells. The experience based review of this component revealed a very small amount of bearing failures. These failures were attributed to two causes: (1) inadequate clamping force in the connecting rod assembly due to inadequate pre-load of the connecting rod bolts, and (2) potential voids and/or impurities induced into the bearing during the casting process. These two items were corrected by: (1) increasing connecting rod bolt pre-load, and (2) performing (NDE) (radiography) of the bearing shells to detect voids or impurities.

Technical Discussion

The original bearings reviewed and supplied by TDI were cast by ALCOA in static molds. These castings were taken by TDI, machined, electroplated with babbit, and then re-machined to final tolerances. Cooper Enterprise (formerly TDI) has informed the nuclear customers that they will begin supplying bearings purchased from a sub-supplier, Federal Mogul Corporation. These bearings are cast via a centrifuge process that is superior to using a static mold in that the centrifuge assures a more uniform placement of equal density material.

Attachment 1 from Federal Mogul offers more details on this issue.

Material Testing

Federal Mogul performed radiographic inspections of bearing shells cast by the centrifuge techniques. These radiographs exhibited dark spots or "ghosts". Several bearings containing these indications were sectioned and metallurgically examined. These images were the result of either (1) material with columnar grains as opposed to equi-axed or (2) slightly lower tin content in the columnar grain areas. The results of the metallurgical examinations concludee that the metal in these areas is equal to the remaining material in mechanical properties; and therefore the shells will perform as required.

Cooper Enterprise has purchased and installed these bearings in several non-nuclear engines. Theses engines have accumulated thousands of operating hours without failure.

Recommendation

Due to the manufacturing change that produces quality casting and favorable operating history, it is recommended that the requirement to radiograph connecting rod bearing shells be deleted. Note that Cooper Enterprise concurs with this recommendation (see Attachment 2).

FEDERAL-MOGUL TECHNICAL CENTER
Engine and Transmission Products
April 16, 1991 #91-Q4 Page 1

ATTACHMENT 1

Cooper Energy P/N 02-340-04-AG: Bearings Rejected by Radiography

Abstract

Bearings rejected by Cooper Energy (25 pcs.) were examined using metallography, microhardness, and SEM/EDS analysis. Conclusion is that dark spots in radiograph (normally indicative of lower density material, porosity, or oxide inclusion) are in this case due to one or both of two possible causes: either (1) small patches of material with columnar grains as opposed to equiaxed, or (2) slightly lower tin content in these columnar grain areas. Consultation with a radiographic expert confirm that the columnar grains can cause such an effect in the radiograph. All metallurgical tests indicate that this metal is equal in mechanical properties to the equiaxed grains, and therefore predict that parts will perform acceptably in service.

Copy to: B. Bridgham, D. Pazuk, A. Sparks, R. Moore, D. Jackson, R. Poehler, G. Pratt, J. Jones, H. Gibson, W. Cook, Ann Arbor File

File Under: B-850, Mooresville, Cooper Energy

Introduction

Cooper Energy purchases heavy wall B-850 bearings from Mooresville for general use. When required for special applications, the bearings are inspected by radiography, prior to use, by an outside lab, on behalf of Cooper. As of April 11, 1991, Cooper reported to Mooresville that they have approximately 25 bearings which they are rejecting due to indications found in radiography. The defect in radiography appears as a fuzzy dark area on the radiographic film. The dark spots appear sporadically, but are more prevalent on one half of the bearing than the other (in other words, the prevalence differs between the top and bottom half of the part as cast.) Unfortunately, there is no way to determine once the part is machined, which half was the top and which was the bottom. Normally a dark patch in the radiograph would indicate a low-density area such as porosity, oxide inclusion, or lack of high density phase (in this case tin).

Discussion

On April 11, a team consisting of B. Bridgham, W. Cook, H. Gibson and the writer attempted to determine the cause of the dark spots. What we found was that the dark spots corresponded to small areas of columnar grains in the material. Figures 1, 2 and 3 show cross sections of the bearing wall, heavily etched with Keller's etch, to reveal the difference in grain structure. In all cases, the columnar grains appear near the ID of the bearing.

However, it should be noted that even though it is near the ID of the part it is closer to the OD than to the ID of the unfinished casting, as there is far more material removed from the ID than the O.D. of the casting during bearing manufacture. Figures 4 and 5 show the actual grain structure, as heavily Keller's etched. It can be seen that the columnar grains are much longer than the equiaxed grains in the lengthwise direction, but possibly a bit smaller in the short direction. An attempt was made to characterize the difference between the two structures.

SEM/EDS studies reveal very little difference in chemical composition between the two regions. Tin content, the most likely material to segregate and cause a difference in density was found (semi-quantitatively) to be 5.5% in the equiaxed area and 5.1% in the columnar region. This small difference probably does not fully explain the dark spot in the radiograph. However, in a paper entitled *Realtime X-ray Reveals Bonus Information* (attached) by Mr. James L. Wheelis of Magnaflux Corporation (Chicago Office), it is described how the abnormalities in radiographs (he terms them 'Ghost Indications') similar to those we see here can be caused by differences in grain structure. It is not known which of these two effects contributes more to the observed dark clouds in the radiograph.

Microhardness (Hv 50 gram) traces were made across the columnar area. A panoramic photo showing the actual indentations is seen in Figure 6. Results of the microhardness tests are as follows:

Equiaxed		Columnar		Equiaxed	
Position	Hardness, Hv	Position	Hardness, Hv	Position	Hardness, Hv
1	62.7	7	63.7	11	N/A*
2	68.3	8	67.0	12	53.2
3	57.5	9	72.5	13	71.9
4	73.8	10	76.3		
5	76.5				
6	64.0			*Unsuccessful test	

Note: All readings are within specification of 50-75 Hv.

Furthermore, one microhardness in each area was taken with the 1 kg load. This load would be less subject to extremely localized aberrations such as grain boundaries and microporosity. Results are as follows:

Equiaxed: Hv 60.3
Elongated: Hv 58.4

The difference between these two numbers is deemed to be insignificant.

In this study, no definite reason for the areas of different grain structures could be ascertained. The most plausible explanation is that the small manifestations of columnar grains represent small parcels of material which froze either on the bottom of the mold or on the sidewalls prior to the beginning of mold rotation. When the mold began rotating, the small pieces of frozen material (with columnar structure, since it froze in contact with the cold surface) was washed away and ended up in its final resting point approximately 15 mm from the casting OD. In order to test this theory, a section was made through a rough casting (unmachined) at the bottom. It is shown in Figure 7. The grain structure revealed can be seen to be the same columnar structure which was seen in the questionable areas. This lends credibility to the proposed theory.

Conclusion:

The dark patches appearing in the radiograph consist of metal with columnar grains as opposed to equiaxed grains. The columnar grains may be slightly lower in tin content. Metallurgical tests indicate that this metal has mechanical properties favorably comparable to that of the surrounding metal. Therefore the appearance of these dark patches on the radiographs is not cause to scrap the bearings.

W. J. Whitney

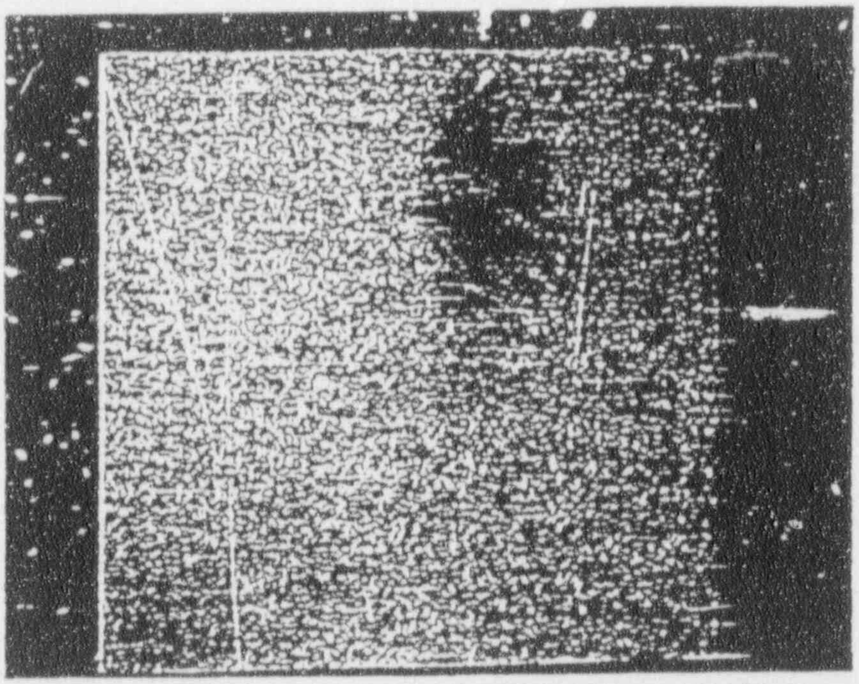


Figure 1. Macro Etched Sample A. 6X. Heavy Keller's Etch. ID is to the right.

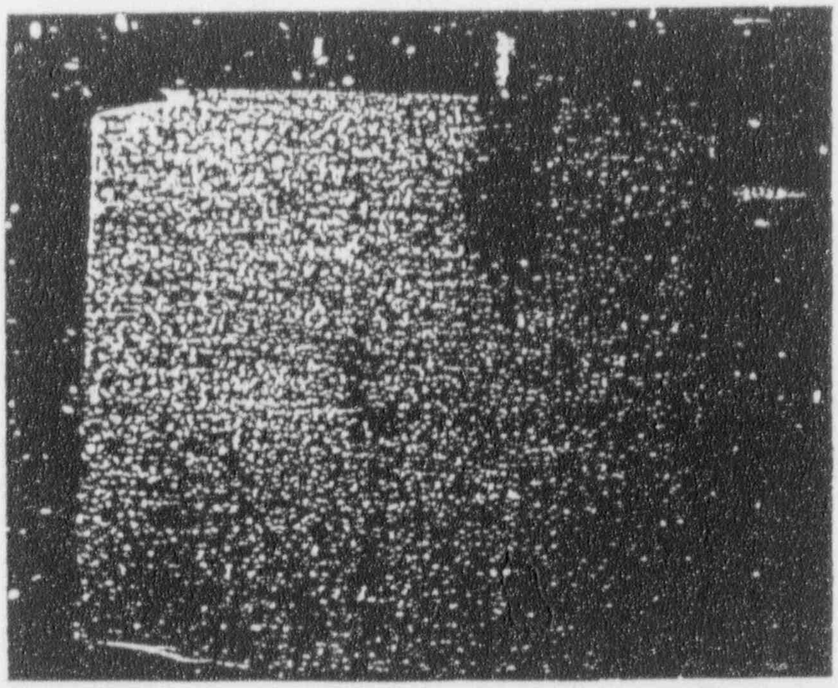


Figure 2. Macro Etched Sample B. 6X. Heavy Keller's Etch. ID is to the right.

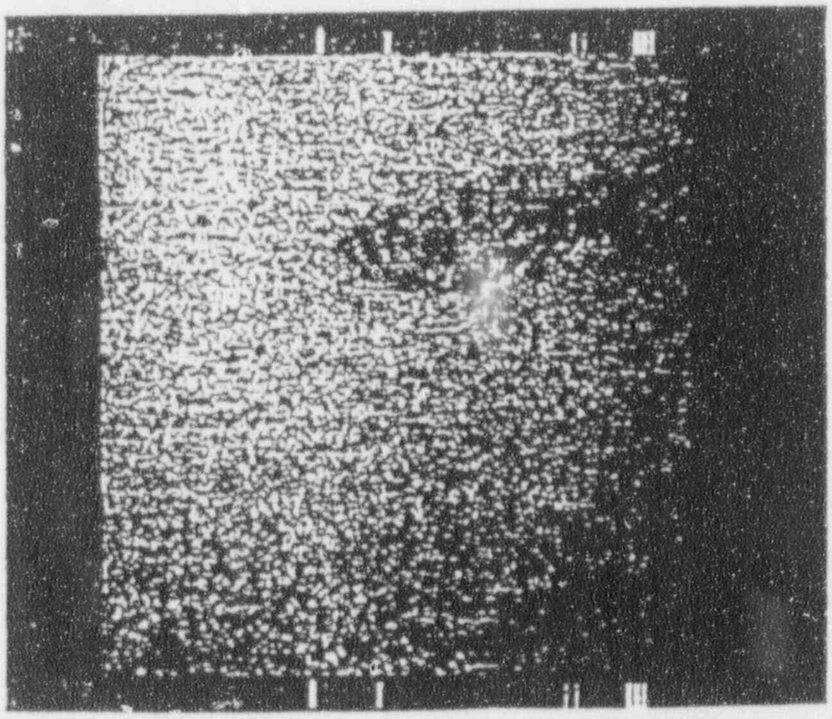


Figure 3. Macro Etched Sample C. 6X. Heavy Keller's Etch.
ID is to the top.

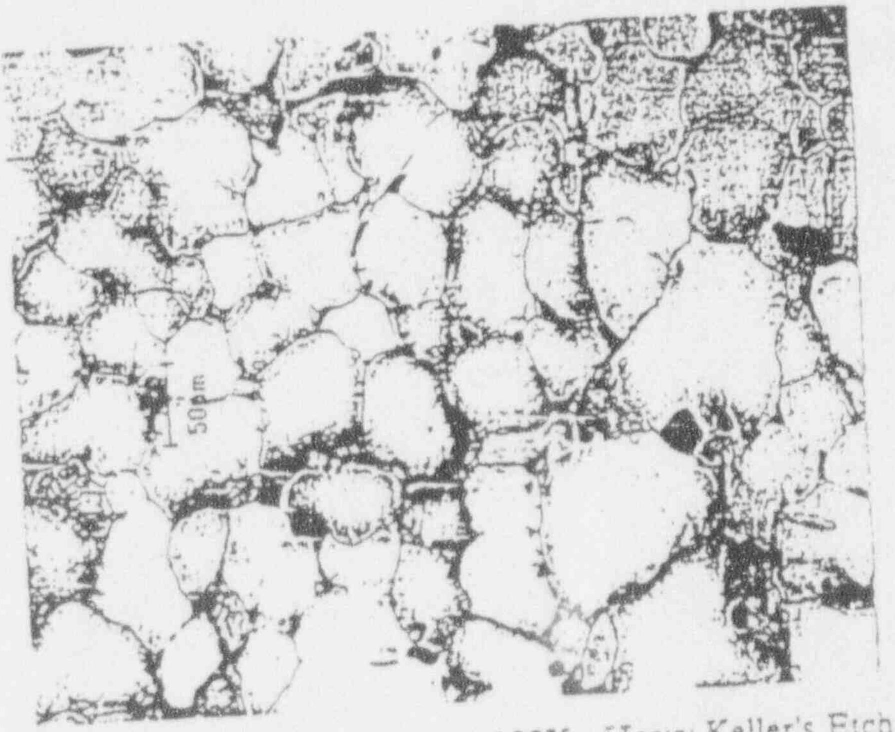


Figure 4. Equiaxed grain area. 200X. Heavy Keller's Etch.

Figure 5. Columnar grain structure. 200X. Heavy Keller's Etch.

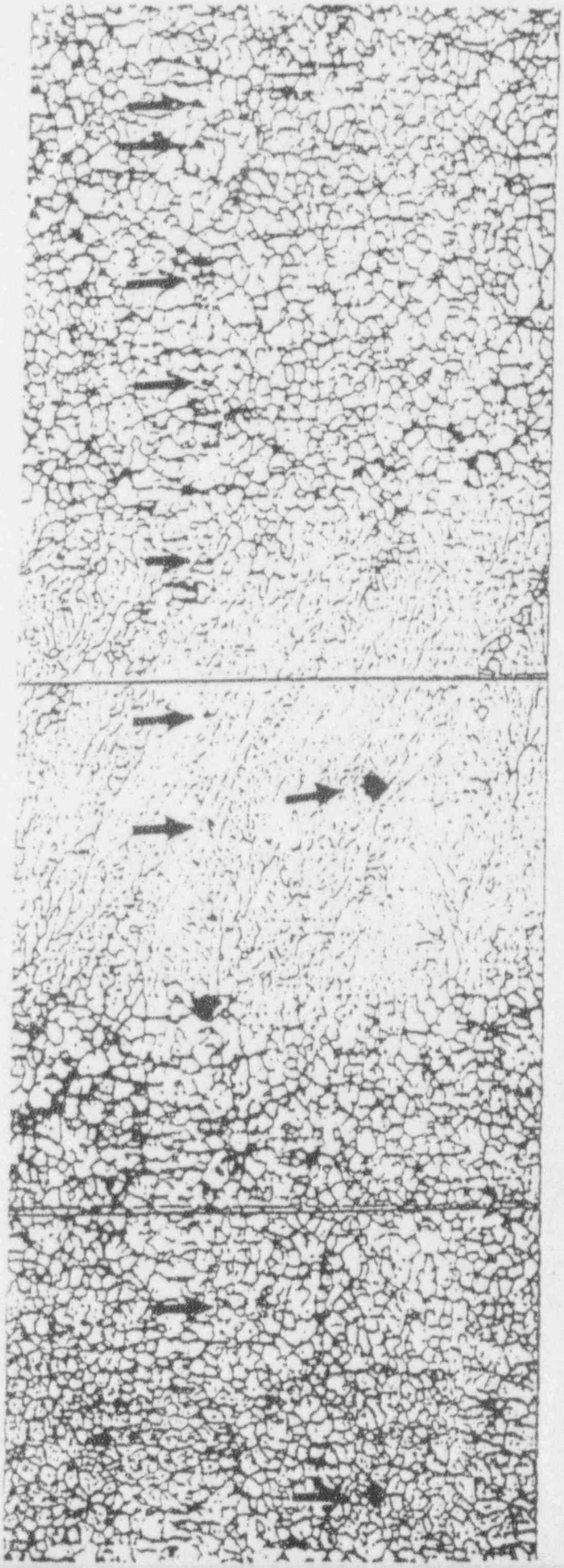


Figure 6. Panoramic view through the columnar area Showing the hardness test indentations. 38X. Heavy Keller's Etch.

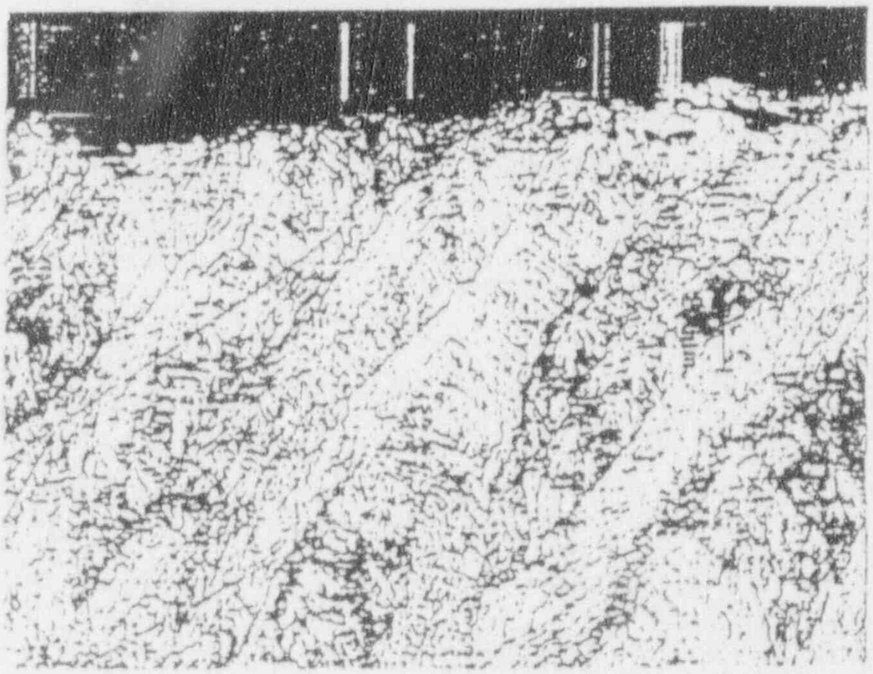


Figure 7. Cross section through surface of unmachined casting. Note similarity to center area of Figure 6. 50X. Heavy Keller's Etch.

REALTIME X-RAY REVEALS BONUS INFORMATION

James L. Wheelis,
Magnaflux Corporation

Presented August 16, 1989 at

the Air Transportation Association
Nondestructive Testing Forum

Special acknowledgement for technical support from:

James Donaldson
Gerald Mason
Michael Moore
Eric Strauts
Ward Rummel

Abstract:

A radiographic phenomenon, termed "Ghost indications", which appear to be but are not necessarily rejectable defects, is described. The ambiguous nature of these indications can result in a sound structure being rejected, or unsound structure being placed in critical service.

The mechanism of the occurrence and a means to differentiate between "ghost" and true indications is explained.

History:

The "ghost" or x-ray diffraction phenomenon has plagued the radiographic inspection business since crystalline structures were first radiographed.

General knowledge of the existence of this phenomenon coupled with extensive destructive verification, has allowed some very experienced radiographers to make judgment calls in noncritical areas. An excellent paper was presented in <u>Material Evaluations</u>, Dec., 1965, Rummel & Gregory " 'Ghost Lack of Fusion' in Aluminum Alloy Butt Fusion Welds", differentiating "ghost" indications from true defects in a specific inspection application.

The increased use of exotic (especially copper bearing aluminum and high nickle) alloys increases the number and severity of diffracted indications. Directionally solidified and single crystal structures are nearly impossible to radiographically inspect without very costly and time consuming techniques. Today, due to these limitations and the extremely critical nature of the air transportation industry, radiographers are justifiably reluctant to make judgment calls. A method which would assist the radiographer in confidently differentiating "ghost" from rejectable indications, could lower scrap rates while assuring that truly rejectable parts do not reach critical service.

Observed Phenomenon:

The operator of the Realtime Microfocus X-Ray Burner Can Inspection System at Northwest Airlines shared his recent experiences with "ghosts" in the image. Indications relating to low X-ray density appear throughout the image ranging from hazy splotches to sharply defined indications.

NOTE: While indications are quite evident on Realtime monitor, fidelity negates reproduction

This unusual phenomenon was nearly always accompanied by:

1. A mottled background to the image.

2. A dull thud in the traditional tap or "ring" test. i.e., an audible Acustic Emmission indicator.

3. Poor ability to hold a sound weld repair..

A window was cut from a part displaying this ghosting and was replaced with a piece of new material so that a direct comparison could be made.

Upon re-inspection of the windowed part, it was observed that the new material displayed neither the mottled background nor the "ghost" indications. Further investigation revealed that the ghost images did not move in coordination with part motion. When viewed dynamically, the indications moved opposite to the part motion; i.e., if the part was moved from the left to right, the indications would move from the right to left; if the part was moved up, the indication moved down. This "antimotion" made it obvious that the indications were diffracted x-ray patterns rather than defect indications.

To fully understand these observations, a study of the material and the mechanism of x-ray diffraction was undertaken.

Material Study:

A section of the part containing both original and new material was removed for analysis. The chemical analysis showed little deviation from the Hastelloy X® analysis supplied by the alloy vendor, Cabot. It was noted that the sulfur content of the surface analysis was a factor of 10 times higher on the old material than either the vendor analysis or the new material analysis.

After discussion with Northwest personnel a consensus opinion was reached that the increase in sulfur content could be related to the stripping process used to remove the heat resistive coating during rework. The main component of the stripping bath is sulfuric acid. excessive retention of stripping solution or poor neutralization may account for increased sulfur content.

On closer observation the surface of the old material shows an extremely rough appearance. (Photo 1) The open and saw-tooth appearance of the cracking also indicated a large grain presence. These observations were supported with a 500x view of the same surface (Photo 2). This view shows very large grains and severe etching at the grain boundaries. Some grains appear as if they could be lifted from the surface. When compared to the new material at 1000x (Photo 3), the evidence supporting the high sulfur content theory is conclusive. The extremely large grains also indicate that this part was not properly annealed.

The open boundaries would account for the mottled image, the dull 'thud' in the tap or ring test, as well as the inability to hold a good weld repair. The ghosts in the image are a result of the X-ray beam being diffracted from the indices of the large grain structure. In this case the appearance of any "ghosting" is an indication of poor or no annealing and is cause for rejection on its own. This information in itself is an unexpected bonus for the realtime inspection. Yet, the study of the x-ray diffraction phenomenon also revealed more universally useable information.

X-Ray Diffraction

The Rummel/Gregory paper was used as base point to study the diffraction mechanism.

Excerpt:[1]

> X-ray Interaction
> When a beam of X-rays strike a crystal, part of the beam is transmitted, part of the beam is scattered. One of the mechanisms for X-ray scattering is by diffraction from the same manner as a grating diffracts ordinary light. Now, if a series of crystals (crystallite planes) are properly oriented with respect to an X-ray beam, a "focusing" effect will be observed on the radiograph, in the form of a dark band (see Figure 6).....
> NOTE : Relabeled Figure 1

Taking this classically correct explanation and graphic display and applying it to the observed phenomenon left one of two conclusions. Either the original observations were not diffraction related or a much more complex mechanism is occurring.

Close comparison of Fig 1 and the recent observed conditions revealed several differences.

---

[1] "Ghost lack of Fusion: in Aluminum Alloy Butt Fusion Welds Ward Rummel and B.E. Gregory Material Evaluations Dec 1965

1. With film radiography the source-to-object distance was sufficiently long to assume near parallel incident rays. With Microfocus Realtime X-ray, the source-to-object distance was under 5 inches and the divergance of the x-ray beam must be considered

2. With film radiography the object-to-film distance is always kept to a minimum, preferably zero. With Realtime Microfocus, the image plane-to-object distance was 15 inches or a 3:1 projection ratio. The travel length of the diffracted ray must now be considered.

3. Weld inspection has a linear area of interest. In this case the diffraction phenomenon could consider only those indications appearing parallel to the weld. Burner can inspection is concerned with any indication in any axis and the diffraction planes are completely random with no preferential alignment.

Grappling with these differences, at length with scratch pad and pencil, lead to the understanding that the mechanism had not changed from the classic presentation (Fig 1), but had multiplied its variables such that it was very difficult to conceive a graphic representation to depict such variables.

An Autocad Graphics Computer and a talented operator made short work of this task, one that had eaten many frustrating hours of free hand sketches. Only when all the variables were laid out and manipulated was a true understanding of the geometric related information conceived. An understanding of this phenomenon leads to the ability to test conculsively whether any indication in any material is caused by x-ray diffraction.

Geometry of X-ray Diffraction

Figure 2 is a graphic representation of observed realtime geometry. Here, beam divergence and source-to-object-to-image plane relationships are taken into consideration.

To clearly understand the antimotion phenomenon, we must consider an individual ray trace. From Theory of X-ray Diffraction in Crystals (W.H. Zachariasen, Dover Publishers, published 1967), we accept the given that the diffracted beam will exit the indices at an equal and opposite angle to the entrance of the incident or primary ray. Using this given, we can now look at one event (Figure 3), in the A position, then moving only the diffracting indices to the B position. The resulting opposite shift of the diffracted beam now supports the "anti-motion" in the observed realtime x-ray image.

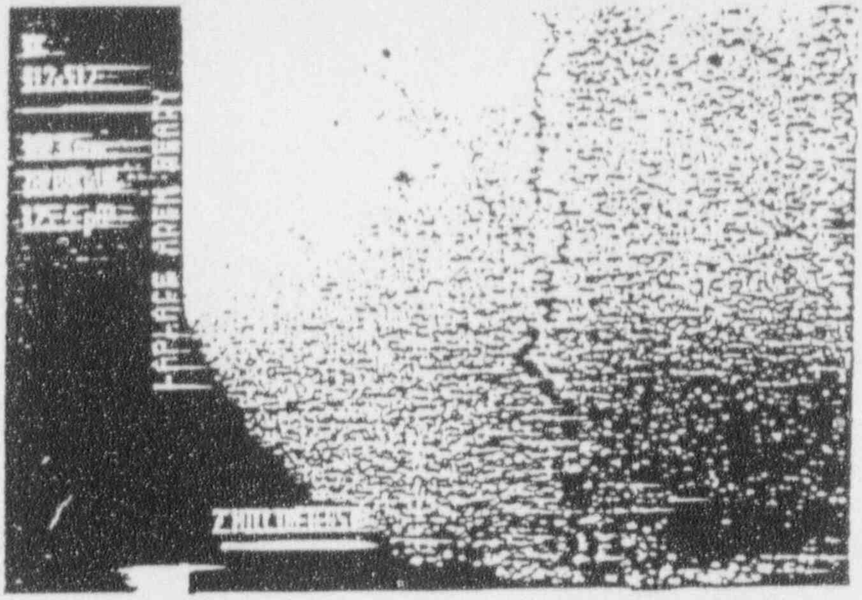
Even more interesting is the effect of varying the object-to-image plane distance. If the ratio of source to object vs object to image plane is 1:0, equal motion occurs. If the ratio is 1:1, no motion is apparent in the diffracted indication when the object is moved. At 1:2 ratio, equal but opposite motion occurs.

Displaying this in three dimensions (Figure 4) thus accounting for the cone of divergent radiation and the vertical and diagonal effects can be comprehended.

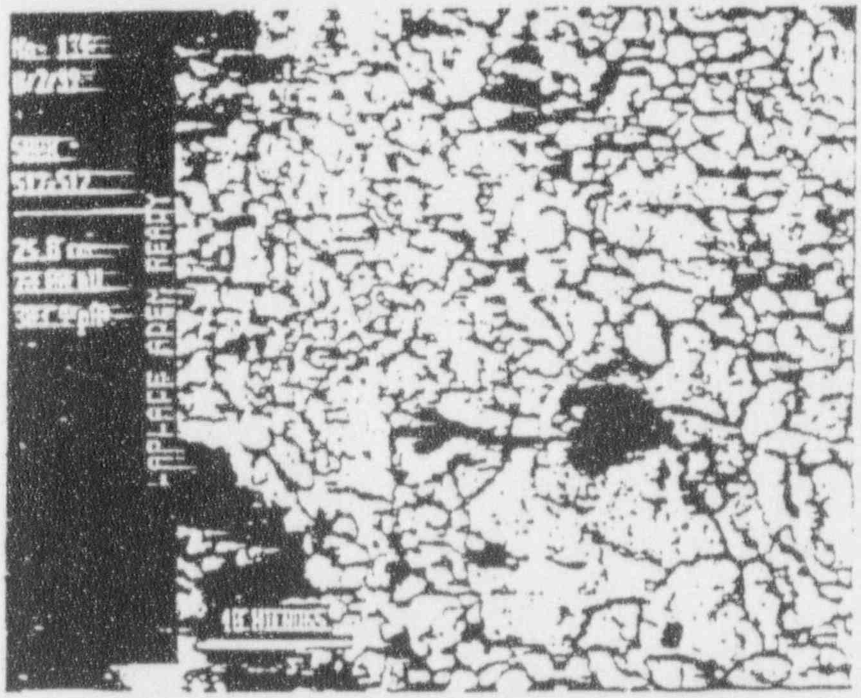
Conclusion:

Using the geometric effects as explained here in the operator of realtime x-ray imaging equipment can conclusively identify diffraction phenomenon. By varying the position under known source-to-object-to-image plane geometries diffracted indications will vary in a predictable manner.

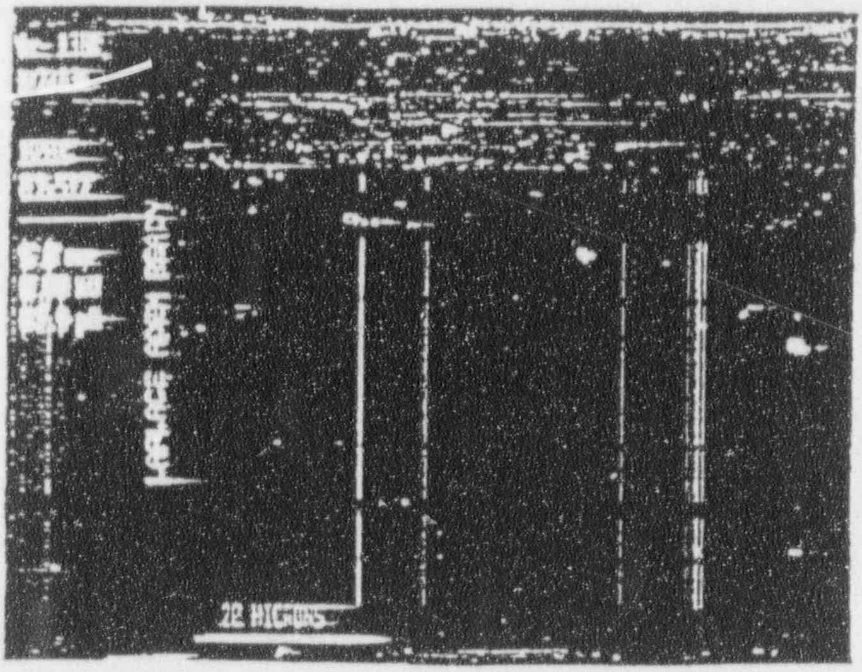
When using an x-ray source of sufficiently small focal spot to allow some variation in object-to-film distance, a film radiograph could be reshot to confirm the origin of suspicious indications.



(Photo 1)

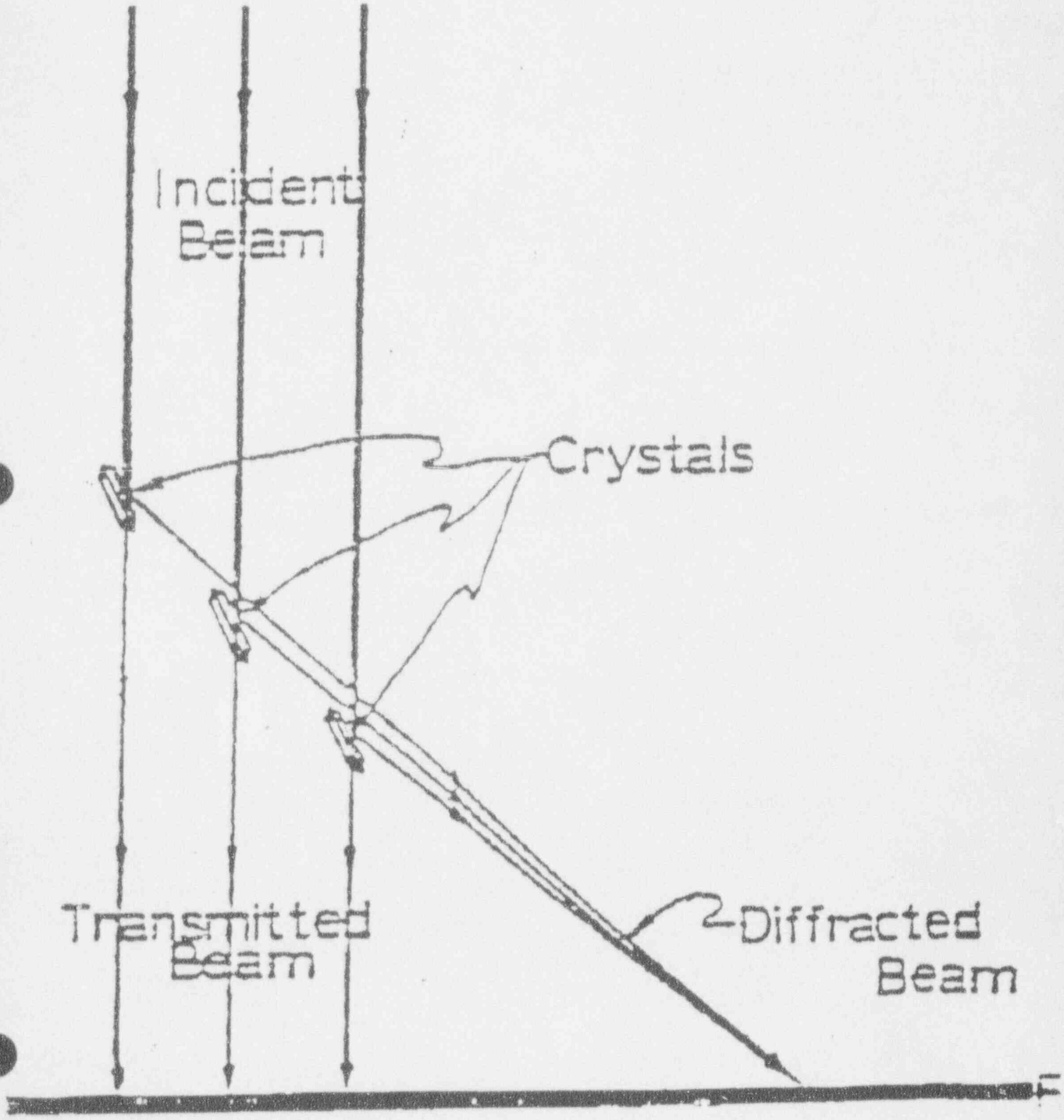


(Photo 2)



(Photo 3)

FIG. 1


Incident
Beam
Crystals
Transmitted
Beam
Diffracted
Beam
F

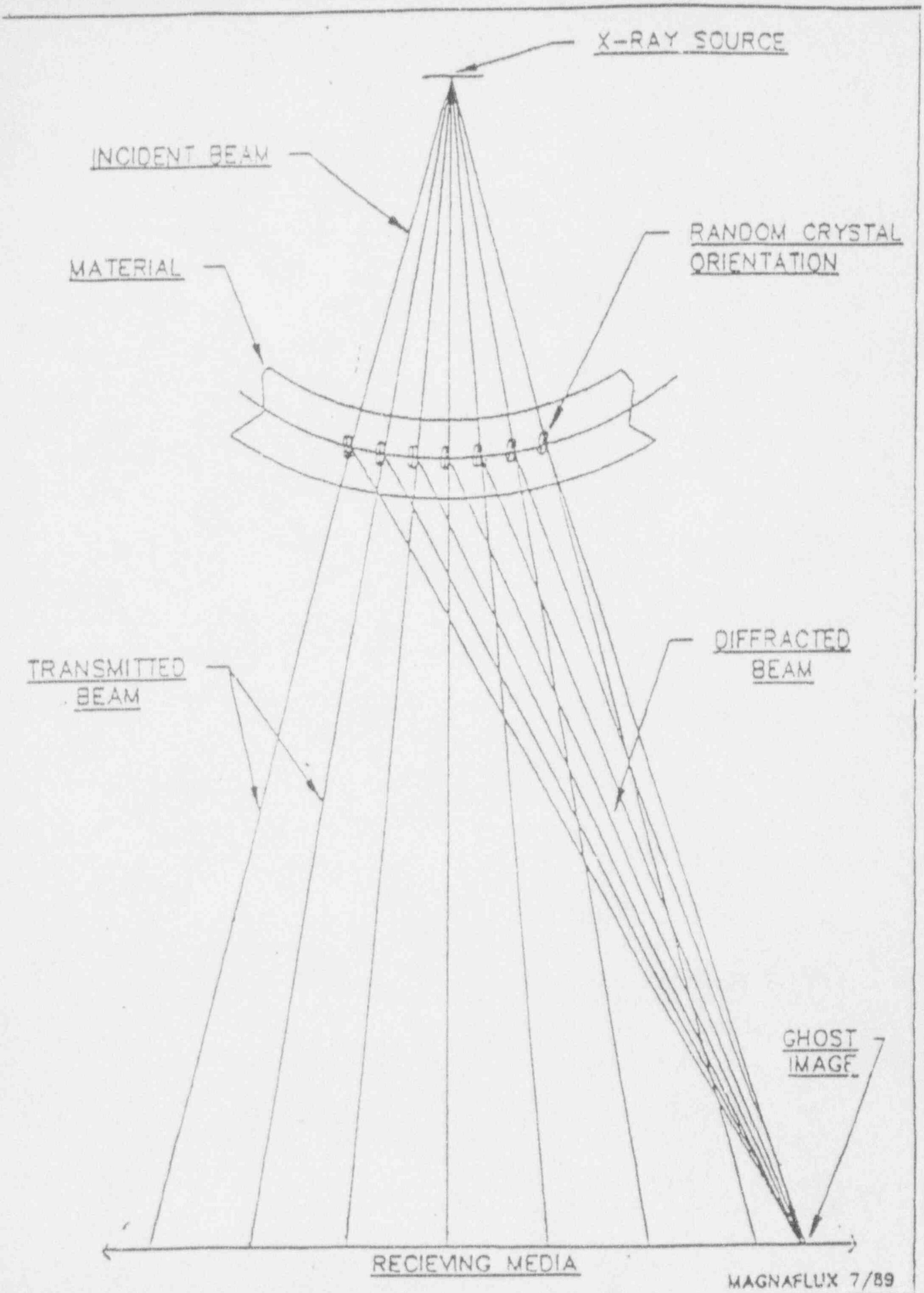
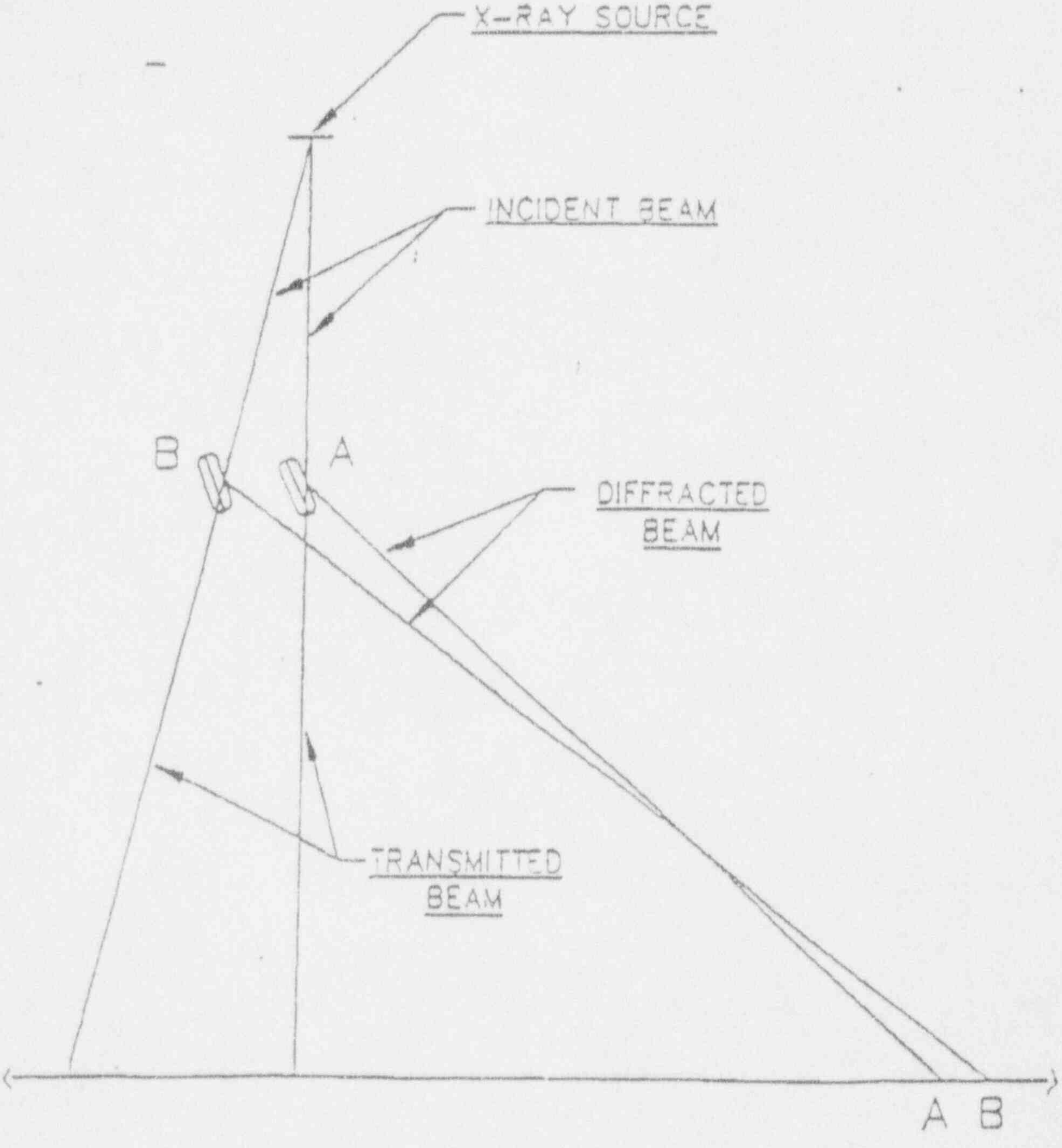
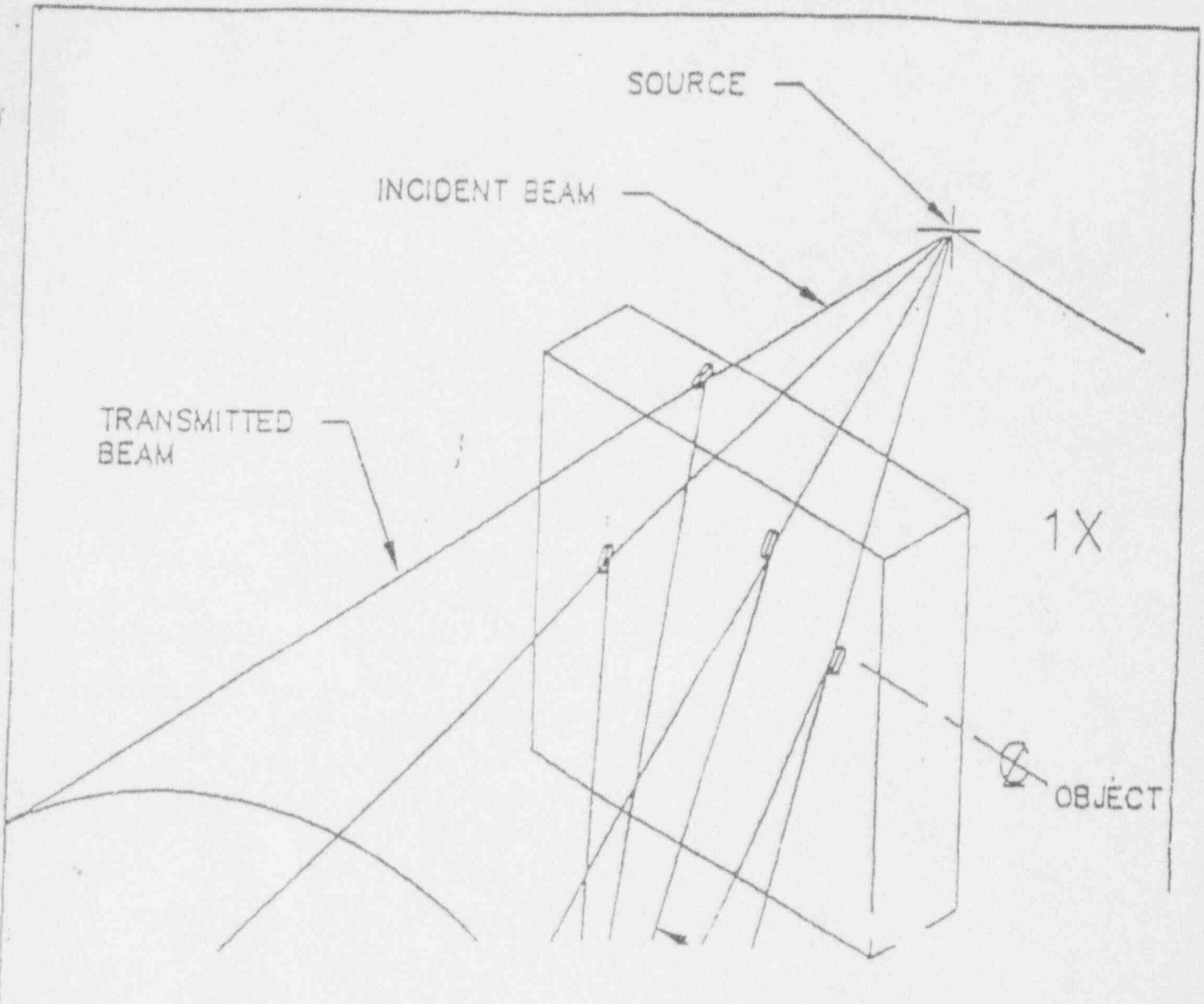

X-RAY SOURCE
INCIDENT BEAM
RANDOM CRYSTAL ORIENTATION
MATERIAL
TRANSMITTED BEAM
DIFFRACTED BEAM
GHOST IMAGE
RECIEVING MEDIA
MAGNAFLUX 7/89

FIGURE 2



MAGNAFLUX 7/89

FIGURE 3


SOURCE
INCIDENT BEAM
TRANSMITTED BEAM
1X
OBJECT

ATTACHMENT 2

CPSES 9117826
SU 910310
July 15, 1991

TO: J.B. George

SUBJECT: Radiography Requirement for Enterprise Bearings

REFERENCE: DR/QR RReport 02-340 B

Referenced report, prepared by a consultant to the owner's group, suggests that TDI bearings will be acceptable provided they pass a radiographic examination performed by that consultant. This study was initiated as part of the owner's group effort to qualify TDI diesels and included such events as discovery of cracked connecting rod bearings at Shoreham in 1983, and reports from TDI Vee Engine owners of cracked bearings. Portions of this report have not been endorsed by Enterprise as discussed below.

Bearing shell cracking has never been a problem in the in-line engines such as used at Shoreham. It has always been our contention that the cracking noted there was caused by use of connecting rods with an extremely large bore end chamfer, which allowed the bearing ends to be unsupported, combined with significant engine overloading. The con-rod condition was corrected immediately. No more cracking occurred.

Vee engines in those days utilized connecting rods assembled with what we now know was insufficient fastener preload, causing excessive flexure, or micro-distortion of the big end of the rod. This condition caused the highly publicized con-rod rack tooth fretting phenomena. Of greater importance however, was the effect of this flexure on the rod bearing, especially if that particular bearing was brittle, i.e. of extremely low ductility. Most of the failure analysis studies done at Enterprise on bearings which cracked for no immediatley apparent reason reported bearing shell elongation numbers either nil or less than 1%. Some had regions of casting porosity on or near the crack surface, but most did not.

TDI supplied bearings made and plated in their factory from Aluminum/Tin castings made at Alcoa in Cleveland. These castings were statically cast in a permanent mold and, from time-to-time exhibited less than adequate mechanical properties. Porosity was also sometimes a problem, and resulted in inability to satisfactorily electroplate the lining on the piece, easily detectable in the plate shop. Note also that pores as small as .010"/.020" were easily visible. In no case would pores of .050" allow plating to be acceptable.

In the early 1980's the fastener preload on Vee Engine con-rods was significantly increased. Rack tooth fretting, while still not zero has been reduced from very significant to almost nil. In the mid 1980's, destructive testing of each heat of bearing castings was begun to verify adequate mechanical properties.

Operating experience after these changes was most satisfactory, bearing shells routinely lasting 20,000/25,000 hours (BY NO MEANS 38,000 HOURS). Shells are replaced based on wear limits rather than base metal condition, in conjunction with general overhaul activities near this hour level. None of these bearings were radiographed.

In 1988, Enterprise ceased manufacture of bearings, opting to purchase these parts in finished form from Federal Mogul, a worldwide supplier of all kinds of engine and compressor bearings, including bearings for engines which could have been installed in nuclear generating stations. F-M is not aware of any radiograph requirement for these parts.

F-M uses the centrifugal casting method to obtain consistantly high quality castings. This method affords the foundryman various options such as mold spinspeed, pour rate and cooling rate to further enhance casting quality. F-M asserts this fine tuning is normal and on-going, and may be the cause of radiograph ghost imaging, as the report I gave you suggests. F-M furthermore applies a flash of plating to the back of the bearing, the lead/tin content aggravating X-Ray problems, but improving its grip in the housing. F-M bearings have been in use in Enterprise Vee Engines for thousands of hours. No reports of bearing quality problems have been received. None of these bearings were radiographed.

In summary, I submit that the onerous radiographic suggestion of referenced report was of questionable value in the beginning, and certainly is of no value now. Not only have the con-rod problems finally been solved with the use of adequate fastener preload applied by hydraulic tensioning tools, but also the bearings are manufactured by avendor specializing in this work, utilizing a completely different methodology than the TDI/Alcoa method employed.

M. H. Lowrey

M. H. Lowrey
Cooper Industries

Distribution:

M. L. Bagale
Ken Dixon
Bo Weir

APPENDIX D

DUKE ENGINEERING
& SERVICES, INC.

230 South Tryon St.
P.O. Box 1004
Charlotte, NC 28201-1004

Bus (704) 373-2473
Fax (704) 373-2695

February 27, 1992

Mr. P. Om Chopra
Office of Nuclear Reactor Regulation
Electrical Systems Branch (MS 7 E4)
U. S. Nuclear Regulatory Commission
Washington, DC 20555

Re: Cooper-Enterprise Clearinghouse Group
Diesel Generators
Position Paper on Radiograph Requirements
for Connecting Rod Bearing Shells
File: MTS-4086

Dear Mr. Chopra:

Enclosed is additional information to clarify questions in regards to certain proposed process changes related to radiography of the connecting rod bearings. This information supplements our previous letter dated October 31, 1991.

The Cooper-Enterprise Clearinghouse Group requests you review the enclosed document and based upon the complete technical justification provided, evaluate and concur with the Clearinghouse that current radiographic requirements are not necessary for Cooper Enterprise EDGs.

Response to this issue by March 20, 1992 will be greatly appreciated by the Clearinghouse and the individual utilities members. Should you have questions, please direct them to Rick Deese at (704) 875-4065.

Very truly yours,

for V. M. Anthony
R. D. Broome
Project Manager
Cooper-Enterprise Clearinghouse
Duke Engineering & Services, Inc.

J. B. George
Chairperson
Cooper-Enterprise Clearinghouse
TU Electric

RDB/VMA/021492

Federal-Mogul Corporation
451 County Line Road
Mooresville, Indiana 46158
Tel. 317-831-3830
Fax 317-831-7035

FEDERAL MOGUL

January 24, 1992

Jules Hudson
Cooper Energy Services
14490 Catalina St.
San Leandro, CA. 94577

Mr. Hudson:

In response to your fax dated January 10, 1992; there are many processing techniques to reduce or eliminate the existence of gas entrapment within the bearing.

Here at the Mooresville facility, we use the centrifugal casting process. This process inherently lends itself to the elimination of gas bubbles, drosses, and oxides due to the outward radial force (approximately 30-60G) acting on these particles. Since the densities of the aforementioned particles are considerably less than any element in the AA 852.0 alloy, they are forced to the inside diameter of the casting were they are removed by subsequent machining.

To further insure the removal of gasses, hexachloroethane tablets are dispersed into the melt. The tablets decompose to evolve chlorine gas which, in turn, ties up the hydrogen (the primary cause of entrained gas in aluminum) and removes it from the melt. Past foundry testing using reduced pressure tests confirm the expulsion of hydrogen gas via this method.

In addition to production techniques, the process is closely monitored to verify the continued success of these techniques. These include: Individual Process Set-Up Sheets for every job, First Piece Inspection of casting, Fluorescent Penetrant Testing of each heat, and Verification of Mechanical Properties of each heat.

Enclosure

cc: E. B. Tomlinson (NRC)
Clearinghouse Representatives
R. J. Deese

I hope that this information assists you in your communication with the NRC. If you need any additional information, please feel free to contact me.

Sincerely,

Brett L. Bridgham
Plant Metallurgist

Copy: D. Jackson
R. Moore
D. Pazuk
Mooresville Lab File

Process Set-Up Sheets:

For every job cast, a Process Set-Up Sheet (see attached) is generated and released to the foundry prior to production. The Process Set-Up Sheet contains all of the vital process parameters needed to produce a particular casting. In addition, it provides documentation of any changes to an existing parameter.

First Piece Inspection of Casting:

Standard practice dictates that first piece inspection be performed on the first casting poured on a job. After cast, the casting is allowed to cool to approximately 300-400 F. The casting is then fractured to reveal four (4) distinct cross sections. These cross sections are evaluated under 10x magnification and inspected for dross inclusions, layering, gas voids, and excessive shrink cavities. This evaluation is documented on the Process Set-Up Sheet.

Fluorescent Penetrant Testing:

The Requirement for fluorescent penetrant inspection (Zyglo) is indicated of the Process Set-Up Sheet. The majority of large castings (>10 - 11 in. dia.) are tested in this manner. A sample casting is poured prior to production and bored to the blue print dimension. The bore surface is evaluated for surface discontinuities which may or may not have been apparent during analysis of the fractured casting.

Mechanical Properties:

At present, a representative casting (termed "lab sample") is poured for each individual heat. This casting provides for both chemical and mechanical testing. Test bars are cut from the lab sample and tested for tensile and elongation properties. This testing provides confirmation that no detrimental defects exist within the test casting.

Under current evaluation is the potential for using separately cast test specimens (.505" standard ASTM tensile bars) to predict the acceptability of production castings. Since the separately cast bars are not under the influence of head pressures greater than 1 x gravity, they will be affected by discontinuities to a greater degree. Therefore, acceptable results obtained via separately cast specimens would insure a degree of confidence in the centrifugally cast product.

DE&S
Duke Engineering & Services

230 South Tryon Street
P.O. Box 1004
Charlotte, NC 28201-1004

(704) 382-9800 Bus
(704) 382-8389 Fax

May 3, 1993

Document Control Desk
Nuclear Regulatory Commission
Washington, DC 20555

Subject: TDI Owners Group
Generic Licensing Submittal for Emergency Diesel Generators
Conditions of License for Utilities with Enterprise Engines-Rev. 1
File: MTS-4086

Gentlemen:

Attached please find five (5) copies of the subject submittal. This ammended submittal is made on behalf of eight utilities having Enterprise Emergency Diesel Generators (EDG) for emergency standby AC power. These utilities are listed below with the respective plants they operate:

UTILITY	STATION
Texas Utilities, Inc	Comanche Peak
Entergy Operations, Inc.	Grand Gulf
Duke Power Co., Inc.	Catawba
Carolina Power and Light Co., Inc.	Shearon Harris
Georgia Power/Southern Nuclear Operating, Inc.	Vogtle
Cleveland Electric Illuminating, Inc./Centerior, Inc.	Perry
Gulf States Utilities, Inc.	River Bend
Tennessee Valley Authority	Bellefonte

This ammended submittal presents additional background clarification on the relevant issues for the Phase I components and the history collected over the past seven years of performing teardowns and inspections required by NUREG 1216. The conclusions drawn from this data are also presented. Please remove the original copy of this submittal (issued with our December 8, 1992, letter) from its binder and replace the entire document with this ammended copy. Revision "bars" have been placed to the right of any revised paragraph to assist the reader with recognizing where changes have been made.

It is respectfully requested that the staff review this information by June 30, 1993, and permit the utilities listed above to remove these prescriptive teardowns and inspections as licensing conditions to give the utility the flexibility to determine the best way to monitor engine condition while maintaining reliability and reducing unavailability.

Correspondence concerning this issue should be addressed to C. W. Hendrix or R. C. Day.

Sincerely,

J B George
Chairperson
TDI Owners Group

RCDay
for CW Hendrix
Project Manager
Duke Engineering and Services, Inc.

RCD/pja.017

Attachment

ustomer: CES
art No.: R-3313

Die (Conv) : PEL-8
Cast Wt(1) : 180#
Die (CNC) :
Cast Wt(2):

lloy : B850
rtification | Chemistry : Y
| Mechanical: Y

Specification: CES D4998
Zyglo (y/n) : Y
Other :

**************** INITIAL SETUP ****************

etal Temp : 1350
ie Temp : 300
PM : 400
lux : 2#11
ast Start : 2 SEC

ast I.D. : 10"
ast Weight: 180#
.D. Stock : 1.328
.D. Stock : .589
AL. Stock : 4.201

Spray Tower "A"
Nozzle Type (a): 50/10
Locations (a): 1,3,5

Spray Tower "B":
Nozzle Type (b): 50/10
Locations (b): 2,4,6

Water Delay : 15 SEC
Cool Time : 4 MIN
Water Temp :

******************** PRODUCTION HISTORY *******************

OB NO. :
.E. NO. : 91-3033
ATE :

CAST QTY. : 7/14
PCS/HR :

etal Temp __________
ie Temp __________
PM __________
lux __________
ast Start __________

ast I.D. __________
ast Weight __________

Spray Tower "A"
Nozzle Type __________
Locations __________
Spray Tower "B"
Nozzle Type __________
Locations __________

Water Delay __________
Cool Time __________
Water Temp __________

Change	Reason	Result

******************** WEIGHT REPORTING ********************

Date	Shift	Scrap Lbs	Good Lbs	Fract Cast	Other Scrap	Good Cast	Bal Req'd

TRANSAMERICA DELAVAL, INC.

OWNERS GROUP

NUCLEAR REGULATORY COMMISSION
LICENSING SUBMITTAL

REVIEW OF LICENSING CONDITIONS IMPOSED BY NUREG 1216

Revision 1
May, 05, 1993

NUCLEAR REGULATORY COMMISSION

LICENSING SUBMITTAL

ON BEHALF OF

THE TRANSAMERICA DELAVAL, INC., OWNERS GROUP

FOR REVIEW OF

LICENSING CONDITIONS IMPOSED BY NUREG 1216

5-3-93

Rev. 1

THE TRANSAMERICA DELAVAL, INC. OWNERS GROUP
LICENSING CONDITIONS
TABLE OF CONTENTS

1.0 EXECUTIVE SUMMARY

The Transamerica Delaval, Inc. (TDI) Owners Group recommends the removal of the licensing conditions imposed by NUREG 1216. Based on substantial operating experience and the Design Review/Quality Revalidation (DR/QR) effort for the critical components, the TDI emergency diesel generator (EDG) has demonstrated that special concerns of NUREG 1216 are no longer warranted. Therefore, the TDI EDGs shall be regarded the same as other EDGs within the nuclear industry, and subjected to the standard regulations without the special requirements of NUREG 1216. These conclusions are supported by the information in this document. In addition, this action will improve unavailability of the engines for service, especially during outages, while maintaining current low unreliability levels.

Removal of these conditions from the license will not prevent these activities from being performed in the future. These types of activities should be performed when the components are disassembled for other reasons. The Technical Specifications for each plant currently require that an inspection of the diesel generator be conducted every refueling outage and these inspections should include items needed to maintain the engines in a reliable and available condition. The Owner's Group is currently working with the manufacturer to develop a new maintenance program that incorporates the experience of the owner's of the equipment combined with the experience of the manufacturer. This joint effort will assure that high reliability is maintained in the equipment. For each EDG license requirement that is being removed as a license condition, the Owner's Group will review the future maintenance needed and adopt a program, consistent with manufacturer recommendations, to fulfill these needs.

The basis of the TDI surveillance matrix deals with preventative maintenance, monitoring, and inspections. The latter of this list is by far the largest contributor to the significant out of service times experienced in outages. In addition the requirement to perform an overhaul every 10 years (a complete overhaul has not yet been performed after 10 years of operation) will add even more to the unavailability of the engines during outages. The overhaul frequency is discussed in detail in Section 3.1. This submittal addresses a solution to reduce unavailability by reducing engine teardowns and inspections. This will be accomplished by more closely monitoring and trending the data that is already being collected. Teardown and inspection will be performed when indicated by the maintenance/monitoring and trending programs for the engines.

Acceptance of this submittal will reduce unavailability and will comply with Station Blackout levels of unreliability which will reduce the risk of core melt as noted in work that has been performed on Station Blackout Issues. Acceptance will also help these utilities prepare for the issues to be addressed by the Maintenance Rule.

The TDI Owners Group therefore requests the NRC to review the revised recommendations contained within this report and issue a generic Safety Evaluation Report (SER) endorsing removal of the component based License Conditions that are currently required by certain power plant Operating Licenses. This generic SER would then be referenced by individual licensees to process Operating License amendments on each docket for plant with TDI diesels to remove these License Conditions. All aspects of the maintenance and surveillance programs would then be controlled by the licensee and reviewed by the NRC under current regulations which is the condition that all other plants operate under.

2.0 INTRODUCTION AND BACKGROUND

The Design Review/Quality Revalidation (DR/QR) effort of 1984 has been performed on Emergency Diesel Generators (EDG) supplying emergency AC power for the following utilities that are in support of this licensing submittal:

UTILITY	STATION
Texas Utilities, Inc	Comanche Peak
Entergy Operations, Inc.	Grand Gulf
Duke Power, Inc.	Catawba
Carolina Power and Light, Inc.	Shearon Harris
Georgia Power/Southern Nuclear Operating, Inc.	Vogtle
Cleveland Electric Illuminating Co./Centerior Energy	Perry
Gulf States Utilities, Inc.	River Bend
Tennessee Valley Authority	Bellefonte

(Note that not all engines at all plants have completed DR/QR as indicated in the particular docket; but each utility has a representative sample of engines that have completed this inspection and have operational hours since the inspections). This effort was in response to NRC concerns regarding the reliability of large-bore, medium speed diesel generators manufactured by TDI for application at nuclear power plants. The scope of this submittal and review is limited to the utilities and concerns of their specific engines. Concerns and items of other engines at other utilities are not addressed and are considered valid and applicable to those utilities by the Owners Group. An explanation of the other utilities originally involved in the DR/QR effort but <u>not</u> a part of this action follows: Southern California Edison remains a current member of the Owners Group, however due to a decision to decommission, Unit 1 of the San Onofre plant is not a participant in this action. Long Island Lighting and Sacramento Municipal Utility District have ceased membership in the Group due to decommissioning actions and are not participating in this action. Washington Public Power Supply and Consumers Power have deferred or canceled plants and are not a participant in this action. This accounts for the thirteen utilities that originally began development of the DR/QR effort.

This effort was originally outlined and documented with the NRC as the TDI Owner Group Program Plan. This plan was accepted by the NRC in an Safety Evaluation Report (SER) dated August 13, 1984. Following issuance of the SER, the Owners Group member utilities developed and implemented the DR/QR in response to the Program Plan. The specific details of the DR/QR were submitted to the NRC for review and this information was reviewed and referenced as part of the NRC position which was documented in NUREG 1216. The recommendations of the NRC consultants hired to assist in this effort is also referenced in NUREG 1216 and is documented in PNL-5600. These details resulted in specific license conditions for each utility as the individual DR/QR reports were submitted under the utilities respective dockets. These utilities have operated for a substantial time period and logged many operation hours on these EDGs and this operational data is being submitted for review to remove the license conditions imposed by NUREG 1216. It should be noted that the scope of the original NRC review was to look in detail at the Phase I components as defined by the DR/QR program.

NUREG-1216 documents the NRC reviews of Phase I and II components. Phase I components are addressed later in this submittal. Phase II components constitute approximately 150-170 components on the engine. The NRC review of Phase II components documented in NUREG-1216 concluded that a detailed review of these items was not necessary and would be redundant.

The Phase I components were chosen as those that had potential for generic concerns. Through an extensive review of TDI and other engine performance data in both nuclear and non-nuclear applications, the Owners Group identified 16 components with such concerns. These are:

- air start valve capscrews
- connecting rods
- connecting rod bearing shells
- crankshafts
- cylinder block
- cylinder heads
- cylinder head studs
- cylinder liners
- engine base and bearing caps
- engine mounted electrical cable
- high pressure fuel injection tubing
- jacket water pump
- piston skirts
- push rods
- rocker arm capscrews
- turbochargers

These engines have operated under the requirements of the program reviewed and approved by NUREG 1216. This document presents the results of the operation of a large sample of engines under that program and demonstrates that the reliability of these engines is comparable to the reliability of other EDGs and that the time required to continue to perform teardowns and inspections as outlined in specific licensing conditions substantially adds to the unavailability of the engines. Subject to the findings of this report, the Owners Group concludes that these engines can be operated in a safe manner without degrading reliability and still achieve improvements in unavailability by removing license conditions to perform inspections requiring engine teardown.

The Owners Group will develop a performance based maintenance program outside of the licensing environment to assure that the goals outlined above will continue to be met.

3.0 COMPONENT PERFORMANCE REVIEW

This section discusses the original component concerns, the proposed modifications/inspections that were subsequently required, the results of the modifications/inspections, and a proposed disposition of each item. The proposed resolution of these items has been discussed with the manufacturer and they are in agreement with them. The modifications/inspections that will be discussed are listed in the DR/QR report, Appendix II, Part B. A copy of the current version of Parts A and B of this Appendix is included as a part of this submittal as Appendix A. Appendix A and NUREG 1216 are the basis for the license conditions that are imposed on some utility dockets. The original review contained in the above documents along with the results of the inspections performed since that initial review was completed will be the review basis for the amended recommendations to be approved by the NRC.

3.1 ENGINE OVERHAUL FREQUENCY

The overhaul frequency for the TDI engines was originally recommended to occur at an approximate 5 year interval. This interval was later revised to 10 years because (1) of the comprehensive DR/QR effort conducted for each of the engine components, (2) of the limited number of operating hours for the engines in nuclear standby service, and (3) a sample inspection of major engine components will be performed on a one-time basis following 5 years of service. Details of the results of inspections performed during this teardown are outlined in the discussion of the individual components. Overall, the teardowns did not indicate any major problems or suggest that any component had experienced any significant wear. The average number of operating hours logged on an engine in a year is approximately 100 hours. This number is much less than the number of hours typically experienced by non nuclear engines. This mode of operation lends itself to using monitoring/surveillance programs in lieu of hours of operation to determine overhaul frequencies. All utilities have and will maintain a monitoring, trending, and surveillance program to determine the health of the engine and determine when corrective actions, including overhaul, are required.

Collectively, these engines have accumulated over 9000 hours of operation. This provides a significant data base on which to base removal of the license conditions imposed by NUREG 1216.

Recent studies performed for the NRC (Reference: NUREG/CR-5078, PNL-6287, NUREG/CR-4590, NUREG/CR-5057) indicate that for approximately 2 years following a major engine overhaul, EDGs, regardless of their manufacturer, exhibit increased unreliability. This increase is attributed to several reasons. One reason offered is that during disassembly there is a high potential to introduce dirt and other substances that may harm the engine. Another is that disturbing a precision fit system that "wears in" to seat mating surfaces (eg rings and liners, crankshafts and bearings, connecting rods and bearings) can result in alteration of wear patterns that may increase wear or actually cause wear to start and decrease the life of the component. As noted in the above reference, the period following overhaul is a "shakedown" period that is required to produce a smooth running reliable engine. Utilities have and will continue to minimize this impact by performing "break in" runs per the manufacturer recommendations; however, the period for "shake down" extends well beyond the break in run time.

The Owners Group agrees with the findings of the above study. In addition, the results of the 5 year "mini" overhauls have shown no component failures that resulted in a loss of component function and have also shown that operational component wear since installation has been very minimal. All plants listed have completed the 5 year "mini" overhaul for their engines with the exception of Comanche Peak and Bellefonte. To perform a complete engine overhaul for a typical engine could take approximately six weeks during an outage and could make the diesel more unavailable during the outage. Extending the period between overhauls reduces the overall cost that would be incurred for additional parts and labor to install and refurbish components that are no worse from wear than the new parts to be installed. In order to prevent increased unreliability and to reduce unavailability, the Owners Group recommends that an overall frequency not be specified. Individual utilities since 1984 have used a comprehensive maintenance and surveillance program and will continue to use maintenance/monitoring and trending data similar to the information gathered in Table 1 of Appendix II of the DR/QR report, to determine when a particular component would need refurbishment or replacement. This would also give the utility the flexibility to plan for this work to be performed over an extended period in lieu of one outage period and would serve to lower unavailability and lower unreliability. The concept of performing overhauls based on trending and monitoring has been discussed and endorsed by the manufacturer.

3.[illegible] AIR START VALVE CAPSCREWS

PM Recommendations

There are no PM recommendations associated with this component in Part B, Appendix A. Revision 2 of Part B, Appendix A recommended that upon installation of a new capscrew, retorquing should be performed at specified intervals to compensate for gasket creep. When no change in torque is detected, the gasket is fully compressed and the torque will be maintained. This item was removed by revision 3 to Part B as the manufacturer has agreed that this is a proper recommendation and has put this item in their PM recommendations.

Background

The air start valve capscrew have not had a history of failure. The original concern with the component dealt with the component being too long and "bottoming out" in the cylinder head. In SIM 360, TDI recommended a change to use a shorter capscrew and recommended a suitable torque value. This was in response to reports at Shoreham and Grand Gulf where these capscrews had been found to loosen.

Results of Inspections

Loosening of this component or other related problems have not been detected since the utility has either made the change noted above or has verified that the existing capscrew does not bottom out. All capscrews have been properly torqued. This is the justification for removal of this item from Part B and placing this information with the vendor recommendations.

Conclusions

This item was closed under NUREG 1216 and no further problems have been reported. Utilities should continue to follow vendor torquing procedures upon replacement.

3.3 ENGINE MOUNTED ELECTRICAL CABLE

PM Recommendations

There are no PM recommendations associated with this component in Part B, Appendix A.

Background

TDI SIM 361, revision 1 notified the engine owners of potentially defective engine-mounted cables associated with the Woodward governor/actuator and the AIR-Pax magnetic pickup. This memo led the Owner's Group to review in detail the suitability of all class IE auxiliary module wiring and terminations currently installed on the diesel engines. Of special interest was the suitability of this wiring with respect to flame-retardancy of the insulation, qualification to industry standards, routing of conduit, compatibility with circuit requirements, and the need for special requirements such as shielding. Modifications were, in some cases, recommended and all of these modifications were completed.

Results of Inspections

No further problems or issues have been found dealing with this component.

Conclusions

The modifications specified address the concerns with this component and this issue was closed during the initial NRC review. This item was closed under NUREG 1216 with no additional concerns found since that time and this item remains closed.

3.4 ENGINE BASE AND BEARING CAPS (02-305A/02-305C)

PM Recommendations

The base and bearing caps preventative inspections are listed in Part B of Appendix A. Specifically, PM recommendation 1 can be made without a disassembly; PM recommendation 2 does require disassembly but is only required to be performed when the caps are removed for other reasons.

Background

The original Owner's Group design review for this component found adequate factors of safety for all components. Problems encountered with this component are not generic in the engines supplied for nuclear service. Problems that were encountered were with non nuclear service engines resulting from inadequate bolt preload and in one case, marginal strength due to inferior quality of a casting. The NRC review noted specifically that once the caps are installed according to the Owner's Group recommendations and torqued to TDI specifications, they should not require further attention until they are removed for some other reason. It should be noted that inspections proposed in Part B of the maintenance matrix were to validate the findings of the analysis discussed above and were a conservative step to aid the licensing process.

Results of Inspections

For all engines in current service, a metallurgical exam for Widmanstaetten graphite has been made or the recommended three cycle inspection for cracks have been completed and none of the bases have indications of inferior material. Twenty-five separate base inspections have been made with no signs of cracks noted. In addition, hundreds of inspections have been made of the bearing cap and saddle interface for PM item 2 and no problems have been detected.

Conclusions

Based on the positive results of the monitoring and the conservative nature of the PMs, the base inspections should be no longer necessary. The inspection of the cap mating surfaces should continue as good maintenance practice only when the caps are removed for other reasons.

3.5 CONNECTING RODS (02-340A/B)

3.51 DSR-48 Inline Engine

PM Recommendations

The connecting rod preventative inspections are listed in Part B of Appendix A. Specifically, PMs 1,2,4, and 5 require teardowns to perform. PM item 3 is excluded from this discussion as it is the scope of a previous license submittal and is already under review by the NRC. These inspections have been performed on the River Bend engines as outlined in Appendix B.

Background

During the DR/QR review, only one rod failure was reported and that was on a non nuclear application and the failure was due to the possibility of pre-existing defects on the surface of the rod eye and to the higher peak firing pressures used in the engine that had the rod to fail.

The design review performed found no design problems with the rod. However, the NRC recommended that a rod eye and bushing be inspected using an acceptable NDE technique and that all bolts and washers be inspected at the same time.

Results of Inspections

The rods at River Bend have been inspected on a sampling basis at the 5 year interval with no problems found. This was performed on two connecting rods per engine and the associated bolts and washers and bearings.

Conclusions

Sufficient operating hours have been accumulated on most engines such that the connecting rods have been in operation and subjected to a number of cyclic loadings to demonstrate unlimited fatigue life. Subsequent inspections have also shown bearing wear to not be a problem. Based on this information and the initial design review and the positive inspection results, it is concluded that these inspections should not be performed unless the rod is removed from the engine for other reasons. These inspections should be viewed as good maintenance practices and not as requirements.

3.52 DSRV-16 Engines

PM Recommendations

The connecting rod preventative inspections are listed in Part B of Appendix A. Specifically, all PMs with the exception of PM 9 require teardown to perform. PM item 3 is excluded from this discussion as it is the scope of a previous license submittal to the NRC and has been approved.

Background

During DR/QR review, a total of six rod failures were documented. TDI had identified two failure mechanisms in SIM 349. The first was due to fatigue of the link rod bolts resulting from loss of bolt preload. The second mechanism was fatigue cracking of the connecting rod bolts and/or the link rod box in the mating threads. The Owner's Group Design review performed a detailed stress analysis of the rod and looked at fatigue as suggested by TDI. The results of that analysis showed the peak stresses induced by the loading mechanisms are slightly below the fatigue initiation curve for rods with 1-1/2" bolts and slightly above the fatigue initiation curve for rods with 1-7/8" bolts (Reference FaAA Report FaAA-84-3-14). Grand Gulf (Entergy) is the only utility that has engines with the 1-7/8" bolts still in use. The summary of this work is that as long as the bolts are properly torqued the rods will perform with no problems.

Oil Analysis should continue to be performed as this will provide indication of premature bearing wear or bearing problems as babbit will be recognizable in the oil. In addition, any significant fretting of the mating surfaces of the connecting rod will be evident as well. This will be detectable as ferrographic analyses is performed for the oil samples indicating the types of metals in the oil. Also, vibration measurements should continue as well as operation monitoring which will also provide an indication of potential problems with this component.

Results of Inspections

A total of 42 connecting rods have been completely disassembled and subjected to the PMs described above. A total of 1776 bolts have been checked for proper tension during the time since DR/QR. These inspections have revealed no problems and these rods continue to provide good service.

Conclusions

Based on the above, the Owner's Group recommends that further connecting rod disassembly to perform the inspections above on a particular time frequency is not warranted. However, it is the recommendation of the Group that as rods are removed from service for any reason, they should be subjected to the PMs in Appendix A as a good practice but this should not be a requirement. Connecting rods in service at most of the utilities have recorded sufficient hours producing a sufficient number of cyclic loadings to demonstrate unlimited fatigue life for connecting rod assembly. In addition, no problems have been found with connecting rod bearings and inspections have revealed normal wear.

The engines at Grand Gulf are currently limited to 185 BMEP. This derating reduces the stresses associated with fatigue cracking of connecting rod bolts and/or the link rod box and bolts. Based on past positive inspection results and engine derating, the recommendations for 1-1/2" bolting then applies to Grand Gulf as well.

3.6 CONNECTING ROD BEARING SHELLS

This item has been covered in Section 3.5, Connecting Rods and in a previous license submittal currently under review with the NRC. The previous submittals are documented in letters to Mr. Om Chopra dated October 31,1991 and supplemented February 27, 1992 from Messrs JB George and RD Broome. Therefore this item is addressed by reference to previous submittals. (Copies of these submittals are included as Appendix C and D.)

3.7 HIGH PRESSURE FUEL INJECTION TUBING (02-365C)

PM Recommendations

The high pressure fuel injection tubing preventative inspections are listed in Part B of Appendix A. The PMs do not require teardown to perform; however, the requirement to eddy current the non shrouded tubing prior to bending does result in considerable cost and delay of replacement tubing. Use of shrouded tubing has been approved by the Owners Group and the vendor to provide protection of leakage that would potentially result in a fire hazard. Fire hazard and personnel safety are the primary concerns with failure of this component.

Background

The review of this component during the DR/QR process revealed that failures had occurred at Shoreham and Grand Gulf Nuclear Stations. A 10CFR21 notification was issued on 7/20/83 by TDI alerting Owners and the NRC of the condition and identified that the cause of the failure stemmed from a draw seam that acts as a stress riser on the inner surface of the tube. One of the points stated is that a draw seam is induced during the drawing phase of the manufacturing and generally will extend over most of the length of the tube and be readily detectable. The design review noted that the tubing is acceptable as long as no preexisting flaws greater than a depth of .0054" existed. This prompted the recommendation to eddy current the tubing prior to bending. The reason for the concern was to prevent leakage that could potentially result in a fire and for personnel safety.

Results of Inspections

The tubing is visually inspected for leaks during each engine run. Since the DR/QR effort, four tubing failures have occurred. This inspection has resulted in hundreds of inspections of this component. Most engines are now equipped with the shrouded tubing which permits the leak check to be performed by removal of a plug. Shrouded tubing is a double wall tube that contains the high pressure fuel spray in the event of a leak and prevents fire and hazards to personnel.

Conclusions

The Owners Group recommends that visual inspections for leaks continue during the engine runs. Any problems should be readily identified by this process. In addition, replacement tubing must be shrouded. Further, because of its double wall design, use of shrouded tubing would eliminate the need to eddy current this tubing and this requirement should be deleted for shrouded tubing.

3.8 CRANKSHAFTS (02-310A)

3.81 DSR-48 Series Engines

PM Recommendations

The site specific preventative inspections are listed in Part B of Appendix A. All of these inspections require disassembly to perform. These inspections have been performed on a per PM basis as detailed in Appendix B.

Background

In August 1983, the crankshaft in the EDG 102 engine at the Shorenam Nuclear Power Station fractured during plant preoperational tests. The fracture occurred at the crankpin journal of cylinder No.7 and involved the web connecting the crankpin to an adjacent main bearing journal. Following this failure, several cracks were discovered in the crankshafts of the other two TDI diesels at Shorenam. These crankshafts were found to be deficient and were replaced with a different design that increased the diameter of the crankpin from the original 11" to 12". The replacement crankshafts were analyzed by the Owner's Group and by NRC and found acceptable for use.

The EDG engines at the River Bend Nuclear Station have crankshafts of the same dimensions as the replacement shafts at Shoreham. However, the generators and flywheels differ between the two installations, resulting in differences in crankshaft torsional stresses. Also the fillet radii at Shoreham are shotpeened while those at River Bend are not. The review and inspection made by the Owner's Group found that there were no relevant indications in the oil holes of the crankpins. However, the analysis revealed that crankshaft torsional stresses in the Shoreham engines at an operational load of 3300kw was equivalent to the torsional stresses in the River Bend engines at an operational load of 3130kw which accounts for the differences in the torsional systems. Therefore, the River Bend engines have been derated for nuclear operation to 3130kw with the crankshafts that are currently installed. No indications or other problems have been found by the inspections and the shaft has accumulated sufficient loadings to demonstrate unlimited fatigue life.

Results of Inspections

The inspections that have been performed are in accordance with Appendix A and has been performed in number as indicated in Appendix B. No indications or problems have been found with this component.

Conclusion

Based on the positive inspection results and on the previous design review, the Owner's Group recommends that future inspections of the crankshaft are not warranted as required by the DR/QR as long as the engine is operated at loads below 3130kw. Should this load be exceeded for an extended period, the engine should be removed from service and the crankshaft inspected in accordance with current procedures. Should no indications be found, the unit may return to service and no further inspections made unless the load limit is again exceeded.

3.82 DSRV-16 Engines

PM Recommendations

The crankshaft preventative inspections are listed in Part B of Appendix A. All of these recommendations require teardown to perform.

Background

The crankshafts for the DSRV-16 engines have a crankpin diameter of 13" and the overall crankshaft length is approximately 20 feet 7 inches. These engines have eight crank throws with 16 pistons driven by 8 articulated connecting rod sets. Differences in the generators and flywheels at the various installations result in differences in the torsional stresses. Therefore, each of the crankshafts at each installation were individually evaluated.

The results of these investigations produced similar results. The results are that the component is adequate for its intended service at full rated load and the 110% rated overload. Extended operation at speeds at or near the fourth order torsional vibration frequency modes should be avoided. (These speeds have been documented in Owners Group site specific reports.) In addition, the engine should not be operated for extended periods in an unbalanced condition.

Results of Inspections

Appendix B indicates how many times each of the inspections detailed in Appendix A have been performed. None of these inspections have produced any indication of cracking and most of the engines have operated above the period that would subject the crankshafts to a number of cyclic loadings to demonstrate unlimited fatigue life.

Conclusion

Based on the positive inspection results and the original design review, the Owner's Group recommends that future inspections as required by the DR/QR are not warranted and should be eliminated. The manufacturer has reviewed this conclusion and is in agreement with it.

3.9 JACKET WATER PUMP (02-425A)

PM Recommendations

The jacket water pump preventative inspections are listed in Part B of Appendix A. All PM recommendations require teardown to perform.

Background

The pumps for the DSR-48 and DSRV-16 engines are somewhat different. The original design of the pump for the DSR-48 engines had two failures on the engines at Shoreham that resulted from a fatigue failure originating at the gear/shaft keyway. This pump was subsequently redesigned. The new design removed the keyway on the impeller end and changed the impeller material to ductile iron. The impeller is now driven through its interference fit on the shaft. This later pump design is installed on the engines at River Bend.

Pumps for the DSRV-16 engines were reviewed as a result of the problems with the model DSR-48 engines. At the time of the review, there were no reported failures and the design review concluded that the pumps were capable of serving their intended function with no problems. Since the DR/QR, there are reports of drive gear failures on non-nuclear engines and these have been addressed by the manufacturer through 10CFR21. There have been no problems with the original concern related to the shaft, keyway and impeller.

Results of Inspections

There have been no failures of jacket water pumps in nuclear service since the design changes made as a result of the DR/QR review. Inspections performed as outlined in Appendix B reveal that some pitting of the gear teeth on DSRV-16 engines has occurred during the pump operation. The resolution of this issue will be dealt with through the 10CFR21 process. Additional problems related to the shaft, impeller and keyway have not been identified.

Conclusion

Based on the positive inspection history, future inspections of this component on a time dependent basis as a requirement is not warranted. However, should the pump be removed or an engine overhaul be necessary, the pump should be inspected per the existing guidance.

3.10 CYLINDER BLOCK/LINERS (02-315A/02-315C)

PM Recommendations

The block preventative inspections are listed in Part B of Appendix A. Specifically, PM recommendations 1, 2, and 3 require teardowns. The PM for the cylinder liners does not require a teardown but removal of the injector for access to the liner is required for visual inspection.

Background

The cylinder block provides support for the upper-engine components and contains passageways for the engine cooling water. The block is subjected to both mechanical and thermal stresses and is a grey-iron casting. Although the cylinders in the DSRV-16 engines are arranged in two banks while those in the DSR-48 engines are in a single bank, the two configurations do not differ in block top thickness, cylinder head spacing, upper support of the cylinder liner, and the stud boss region that anchors the cylinder head studs. Minor design changes have been incorporated as a result of DR/QR to reduce the protrusion of the cylinder liner collar above the block top and to increase the cold radial clearance between the cylinder liner and the block, thereby reducing stresses in the block top. Cracks have been reported in cylinder blocks of both DSR-48 and DSRV-16 engines in nuclear and non-nuclear applications.

A thorough design review of this component was completed during the initial DR/QR review. The results of that review were that some of the castings made during the period may contain Widmanstaetten graphite which is an inclusion that weakens the grey iron casting. It was shown that blocks containing this material have a greater potential for crack development. However, it was also shown that should these cracks develop, regardless of the cause, that the block would continue to perform its intended design function and that the cracking would potentially produce a flow path for water to the block exterior. A cumulative fatigue usage index formula was created and an inspection frequency was established based on that usage. Further, it was noted by the Owner's Group and by the NRC that this analysis was conservative and that "If cumulative results of these inspections over several power plant fuel cycles show that one or more of the inspections reveal nothing of significance, the scope and frequency of the inspections could be reconsidered." (Source: PNL-5600)

Results of Inspections

Block top inspections have been performed in accordance with the numbers outlined in Appendix B. Note that some of these inspections are being performed on a partial basis; however, none of the inspections (including those of blocks with widmanstaetten graphite) have revealed any cracks. In addition, no significant liner wear or indications have been found.

Conclusion

Based on the positive inspection results, the Owner's Group recommends that future block top inspections be performed when a head is removed for other reasons for plants that have blocks with no widmanstaetten graphite. For those sites having blocks with widmanstaetten graphite, the recommendation is to perform a visual inspection of the block top under strong lighting during a test run once a refueling cycle. Should cracks be found, the engine should be evaluated for continued service and a more detailed inspection performed at the next available refueling outage. The manufacturer has reviewed these conclusions and agrees with them.

3.11 PISTON SKIRTS (02-341A)

The scope of this review will be limited to Type AE piston skirts. These are the only type skirts currently used in nuclear applications. Recommendations for other type piston skirts are not addressed by this submittal and previous findings by the Owners Group and NRC remain in effect.

PM Recommendations

The piston skirt preventative inspections are listed in Part B of Appendix A. Specifically, the PM listed requires disassembly of the engine .

Background

The design review of this component revealed that design stresses are within the allowables and that based on experimentally measured data, neither crack initiation nor propagation is expected to occur. The AE skirts were tested and validated during DR/QR. The purpose of this validation was to determine the calculated fatigue life of this component. Following the validation, a detailed inspection was made of these skirts with no problems found. These skirts have previously been approved by NRC for use at the rated engine loads and all engines in current service have been equipped with these skirts.

Results of Inspections

Thirty nine piston skirts have been removed and inspected in detail. No problems have been found with this component and these skirts continue to provide good service. See Appendix B for the numbers of inspections.

Conclusion

Based on the positive inspection results of this component and documented design quality, further inspections under the DR/QR program for this component are not required unless a piston is removed from the engine for some other reason. Research identified by this report regarding aging of this component has identified unnecessary teardowns as a real source that contributes to unreliability.

3.12 CYLINDER HEADS (02-360A)

PM Recommendations

The cylinder head preventative inspections are listed in Part B of Appendix A. Specifically, PM 1 requires teardown .

Background

The basic cylinder head configuration is common to all TDI DSR-48 and DSRV-16 engines. However, during periods of manufacturing, TDI made changes to manufacturing practices, quality control, and design. The heads manufactured have been categorized into three groups: those cast prior to October 1978 are referred to as Group I, those cast between October, 1978 and September, 1980 are Group II, and those cast after September 1980 are Group III.

Cylinder heads in Group I and II are subject to core shift, inadequate control of solidification, and inadequate control of the Stellite valve seat weld deposition process. In addition, Group I heads are not stress relieved and are subject fatigue crack growth in thin areas. Heads in Group III are much less prone to all of these problems. It should be noted that heads from all three groups remain in service. Casting defects were found at Shoreham, Grand Gulf, Catawba, and Comanche Peak during the DR/QR process. The net result from the design reviews and flaws, would have been to allow leakage of jacket water to the exterior of the head or to the cylinder. Exterior leakage is of no real concern from a reliability standpoint, but leakage into a cylinder can result in major engine damage. As a result, the Owners Group recommended that the engine be barred or air rolled prior to starting with the air start cocks open to detect any potential leakage. Also, the manufacturer has changed its weld repair procedure to correct previous problems with weld repairs in the fire deck region of the head.

Results of Inspections

Inspections have been performed as detailed in Appendix B. Indications were found on the exhaust valve stem during RFO 4 at River Bend. The indications were caused by a sharp chamfered edge on the rocker arm swivel pad and are direct result of excessive valve lash. The root cause of the excessive valve lash has been attributed to back pressure in the exhaust system during the start sequence of the engine. The chamfered edge on the swivel pad was removed by machining. An improved swivel pad has been developed by the vendor.

The water leak found a River Bend has been investigated by the owner of the engine and the manufacturer. The leak was caused by a thin wall section in the cylinder head casting near a tapped bolt hole. This defect was reported to the NRC under 10CFR21 by the manufacturer. The manufacturer's recommended corrective actions include inservice repair techniques and a permanent repair that will be made during an overhaul of a cylinder head.

Conclusions

Based on the above positive inspection results, PM recommendation 1 is not warranted and should be discontinued. It is the recommendation of the Owner's Group that pre run air rolls and inspections for leaks, prior to any planned start or as dictated by plant configuration, continue to preclude a leak from resulting in major engine damage. Any other type of degradation that could occur will become evident during compression checks, with exhaust temperature monitoring, and monitoring jacket water standpipe level for losses. The previously referenced NRC NUREG reports again point out that major disassembly, such as head removal, may result in increased unreliability and unavailability.

3.13 PUSH RODS (02-390C)

The scope of this review will be limited to push rods of the friction welded design as this is the only design currently in use. Other designs are not addressed by this submittal and the previous recommendations made remain valid.

PM Recommendations

The push rod preventative maintenance inspections are listed in Part B of Appendix A. The recommendation requires an engine teardown .

Background

Design analysis of this design showed that potential buckling under the loads to be imposed was not a concern. Metallurgical evaluations showed no major discrepancies in the chemical composition, hardness, or microstructures of any components. A fatigue crack growth analysis showed that, under cyclic loading, no potential fabrication cracks are expected to propagate in either the main or intermediate push rods using this design. A fatigue test that included 10 to the seventh cycles compressive load from zero load to a value approximately 25% above the maximum theoretical service load, was also conducted. No cracks or indications were found.

Results of Inspections

Over 900 push rods have been inspected following extended service and have shown no problems.

Conclusions

Based on the positive inspection results and the conservatism of the design, future inspections as required in the DR/QR are not warranted and the Owner's Group proposes to delete this item. Should these components be removed for other reasons, Owner's may elect to conduct these inspections depending on the service life and reasons resulting in engine teardown.

3.14 CYLINDER HEAD STUDS

Studs in nuclear service engines have been replaced with the latest design and installed in accordance with the procedures recommended by the manufacturer. This issue was closed in the original NRC review resulting in no preventative inspections for this component. There has been nothing found in subsequent operation of these engines to change this finding.

3.15 ROCKER ARM CAPSCREWS (02-390G)

PM Recommendations

The rocker arm preventative maintenance inspections are listed in Part B of Appendix A. The inspection is a "one time" inspection and has been completed for all engines. The inspection does require teardown.

Background

The review during the initial DR/QR revealed that capscrews failures had occurred on an isolated basis. The cause of the failures was due to insufficient preload on the capscrews. This failure history resulted in the requirements outlined under the PM Recommendations. The Owners' Group performed a detail design review of the component which calculated appropriate resultant stresses, endurance limits, and looked at the material requirements to determine that the material is suitable.

Results of Inspections

Subsequent to incorporating the torque requirements there have been over 500 inspections of this component with no major problems found. River Bend has reported two pop rivets missing; this was disposition as not being a problem as lubrication could still get to the needed areas.

Conclusion

This inspection is currently performed only on reassembly of the rocker arms. This should continue when the rocker arm is removed from service for any reason.

3.16 TURBOCHARGERS (MP022/023)

PM Recommendations

The turbocharger preventative inspections are listed in Part B of Appendix A. Specifically, PM Recommendations 2,4,5, and 6 require teardowns. These inspections have been performed on a per PM basis as detailed in Appendix B. These turbochargers typically see operation hours of approximately 500 hours per 5 year interval.

Background

Turbocharger performance directly affects the design rating of the engine. During the DR/QR review, several bearing and lubrication problems were identified. In addition, there was a concern dealing with the potential for damage of the rotating vane group due to ingesting fragments of material, specifically bolts and blades from the stationary vanes assembly that had failed due to fatigue loadings. The response to these concerns were answered as follows:

1) Lubrication and Bearing Wear

The Owners Group recommended modifications to install the drip and full flow prelubrication system to provide an oil film to the turbo bearings that would drain away during standby and that this system should be activated to prelube any planned start. This recommendation has been implemented by the Owners. In addition, oil sampling was recommended as a means to detect significant bearing wear. PM items 1,3 and 4 relate specifically to this concern.

2) Potential For Damage to Rotating Vanes

During DR/QR review, it was learned that at least one engine in nuclear service had experienced loss of a stationary vane, and from the rotating vane group, bolting material. The net effect of this event was that no significant damage occurred, and the turbocharger performance was not effected. This is documented in NUREG 1216 as referenced. This issue resulted in PMs 1,2,5,6, and 7.

Results of Inspections

PM items 2,5, and 6 require teardown. Appendix B shows the number of times that each PM has been performed. The results of the inspections have shown that in most cases the oil system modifications have resulted in eliminating significant bearing wear. In a case where some moderate amount of wear was found, this was detected via the oil monitoring trends. There is no case where failure occurred due to excessive bearing wear.

Since the original discovery of stationary vane failure and passing of this material through the rotating vane group, three other occurrences have occurred with the same result that the vane fragments passed through the rotating vane group with no significant damage and no significant degradation of turbocharger performance.

Conclusions

Based on the positive inspection results described and detailed in Appendix B, PM items 2,4,5,and 6 are not required. PMs 1,3 and 7 will be continued as a part of the future maintenance program. PMs along with results from the oil sampling program and exhaust temperature trending will show degradation in turbocharger performance and/or indicate increased bearing wear or vane damage. This will permit the utility to evaluate and take actions necessary to correct the problems. Should the turbochargers be removed from service for any reason, the PM recommendations 2,4,5, and 6 should be considered as good maintenance practice.

4.0 SYSTEM UNRELIABILITY

System unreliability for the TDI EDGs has been consistent with the industry median for the period since DR/QR was completed. A review of the INPO data for the period 1/90-12/92 gives a median unreliability for TDI EDGs as 0.0094. This is well within the expectations of NRC guidance for either a plant needing a 0.0250 unreliability or 0.050 unreliability as directed by Station Blackout and equal to the current industry median. Some unreliability has been attributed to the engine teardowns and inspections. Industry experience indicates that elimination of frequent teardown and inspections has resulted in an additional decrease in unreliability. The following table lists the INPO data furnished for unreliability:

INPO UNRELIABILITY VALUE FOR TDI DIESELS

1/90-12/92

ENGINE	UNRELIABILITY
1	0.0000
2	0.0000
3	0.0000
4	0.0000
5	0.0000
6	0.0000
7	0.0103
8	0.0109
9	0.0085
10	0.0250
11	0.0313

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12	0.0336
13	0.0333
14	0.0364
15	0.0115
16	0.0450
17	0.0000
18	0.0000
MEDIAN	0.0094

A review has been made by the utilities having engines 12, 13,14, and 16 as to the cause of the higher unreliability and what is being done to improve the status. The findings are as follows: 1) Some of the INPO numbers have reporting errors and some of these numbers are really better than reported. These utilities are working with INPO to resolve these problems; 2) some utilities have reviewed the failures that were reported as being valid and feel some of these "failures" were conservatively reported and are reviewing the data to determine if the number of valid failures reported is accurate, and 3) in the cases where the numbers are accurate, recent improvements have been noted and the individual utilities are working to address improvements in the program. It should be noted that some failures are hard to detect; for example, a field breaker failure did not show up until the monthly test run. For this item investigation showed that it had failed prior to the run and significant additional time had to be added per the INPO guidelines for the diesel being out of service. It is concluded from the data provided that the unreliability of the TDI EDGs is within the bounds and expectations of the regulatory guidance and other diesels within the nuclear industry.

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5.0 SYSTEM UNAVAILABILITY

System unavailability has been reasonable for the TDI Enterprise engines since DR/QR as measured by the INPO indicators. (The INPO Indicators are based on unavailability during power operations.) The industry median (for all engines) is 0.0182. The median for the TDI engines is 0.0177. The following table gives the unavailability three year values for the TDI engines in service for the period 1/90-12/92:

INPO UNAVAILABILITY VALUES FOR TDI DIESELS

1/90-12/92

ENGINE	UNAVAILABILITY
1	0.0196
2	0.0105
3	0.0106
4	0.0134
5	0.0141
6	0.0190
7	0.0318
8	0.0348
9	0.0165
10	0.0413
11	0.0343
12	0.0405
13	0.0432

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14	0.0650
15	0.0125
16	0.0160
17	0.0101
18	0.0110
MEDIAN	0.0177

Recent industry events have focused more attention on unavailability of safety related systems especially the diesels during modes of operation other than full power operation. The above numbers reflect standard industry practice of determining unavailability during periods of power and non power operation. Review of data from utilities involved with this submittal, accounting for unavailability during outages would substantially increase the median. As an example, assume an outage of 6 weeks for an overhaul on a diesel. This would result in 1008 hours out of service and if this were translated, would result in an unavailability of 11.5% for the year without any other unavailability factored in. In review of data from utilities supporting this licensing request, unavailability numbers in the range of 10-15% (on a per engine basis) would not be uncommon with outage out of service time figured in. By not performing major teardowns, out of service durations during outages could be shortened to two weeks and significantly reduce this unavailability. The numbers presented above also include outage time related to raw water and other systems that contribute unavailable time to the engine; not just the engine itself. In the case of any engine having an unavailability of greater than 0.4, a review has been made and the unavailability for these engines is improving.

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HOW TO USE THIS APPENDIX

Appendix A is a reproduction of Appendix II, Revision 3 of the TDI DR/QR report and is placed here for the convenience of the user. Appendix A provides, for information, the specific Preventative Maintenance (PM) Recommendation that is currently performed on the Enterprise engines. These recommendations describe the inspections performed as well.

Appendix B is a tabular listing of the collective results of the inspections performed that are listed in Appendix II from the utilities listed in Section 2/0. Each table in each Appendix is listed by Component number. Thus, one may look for an item such as Connecting Rods in Appendix B to see the results of an inspection. The component number for Connecting Rods is 02-340A/B which is found in the text by the section number. If one were to need to know what inspection was performed to obtain these results, then one would refer to Appendix A using this component number to find a description of the inspection performed. Some components have multiple inspections listed in numerical order under PM recommendations.

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THE TRANSAMERICA DELAVAL, INC. OWNERS GROUP
LICENSING CONDITIONS
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TDI OWNERS GROUP

GENERIC MAINTENANCE AND SURVEILLANCE PROGRAM

APPENDIX - II

I. INTRODUCTION

The purpose of this appendix is to provide the TDI Owners with a set of maintenance and surveillance recommendations for diesel generator components which have been developed by TDI and/or the Owners Group as a result of the overall Owners Group Program and including subsequent testing and inspections performed following the review conducted by the original program. This appendix is intended to enhance the existing TDI Instruction Manual, Volume I and Volume III, which will maintain the qualification of the diesel generators for the life of the plant.

II. METHODOLOGY

During the implementation of the Owners Group Program Plan, the Owners Group Technical Staff reviewed many sources of information regarding the maintenance and surveillance for the diesel generator components identified in this appendix. These sources included TDI Instruction Manuals, Service Information Memos (SIMs), and TDI correspondence on specific components. The basis of this matrix is formed by the following:

- Owners Group Technical Staff review of TDI Instruction Manuals, SIMs, and TDI correspondence on specific components.
- Technical Staff input regarding the adequacy of recommendations found in sources mentioned above.
- Additional maintenance recommendations identified during the DR/QR review and from 10CFR21 reports and operating experience at nuclear plants.
- Results of subsequent testing and surveillance (i.e., Shoreham EDG103 750-hour endurance run and subsequent engine teardown) performed following the review conducted during the original program.
- Additional review by the Owners Group representatives.

It should be noted that this revision in some cases modifies the original program results based on this additional information and review.

III. RESULTS AND CONCLUSIONS

Proper maintenance is important in ensuring long, reliable and satisfactory service of the emergency diesel generators. Maintenance work, in order to be effective, must be carried out thoroughly and regularly. It is for these reasons that a detailed schedule of maintenance service has been laid out by the Owners Group for the TDI Diesel Generators. This schedule should be followed as closely as the operating conditions will permit. This maintenance service as specified supersedes previous general maintenance requirements, but is separate and does not supersede Quality Revalidation and/or modifications previously recommended. The schedule details specific components requiring maintenance on a regular basis. This schedule separates the maintenance activities into frequencies as set forth in the subsequent list of definitions.

Inspections, as outlined in this maintenance schedule, are to be performed and parts refurbished or replaced as required by the program or deemed necessary by the inspection. Any adverse findings shall be investigated and corrective action, including amended inspection frequencies, shall be implemented unless sufficient justification is present to do otherwise.

This generic matrix, Parts A, B, C, together with Part D entitled "Site-Specific Maintenance Matrix" and the sources defined in Section II form the TDI Maintenance Program. Note that component numbers used in the generic matrix are for Texas Utilities' Comanche Peak Steam Electric Station - Unit 1. Part E provides a cross reference to identify corresponding components for other engines. Also note that a blank in the cross reference signifies that a component is not on a particular engine and, thus, that the Owner would not perform that maintenance item.

Tables 1 and 2 of part A provide engine operating and standby surveillance parameters and standby surveillance parameters and frequencies. It is recommended that the utility address these tables in its operating and monitoring programs. Table 1 addresses operating parameters and is not duplicated in the maintenance schedules; these parameters are to be recorded and/or checked during the monthly testing and any other period of operation. Table 2 addresses the standby parameters that occur on a daily frequency and are not duplicated in the maintenance schedules.

IV. DEFINITION OF TERMS

1. Overhaul Frequency

   a) A complete engine teardown inspection will be performed every 10 years. The utility has the flexibility to inspect one engine/reactor unit at the End of Cycle (EOC) prior to 10 years and the other engine at the EOC following 10 years. Alternately for PWR units, the inspection may be performed coincident with the 10-year reactor vessel inservice inspection. This will permit both engines for each unit to be disassembled in parallel since one engine will not have to remain in service with the reactor vessel off loaded. (For reactor units having three engines, the inspections are to be carried out as above with the third engine to be inspected at the second EOC following 10 years.) The 10-year interval will typically be taken from issuance of the Low Power

Operating license or from subsequent teardown and inspection for plants already in operation.

b) A one time inspection will be performed at the EOC closest to five years. For a unit, one engine may be inspected at the EOC prior to five years and the other at the EOC after five years to minimize plant outage length. (For reactor units having three engines, the inspections are to be carried out as above with the third engine to be inspected at the second EOC following five years.) This inspection will generally involve the same components as the 10-year teardown; however, only a sample of items for some components will be inspected as set forth in the maintenance schedule. During this five-year inspection, any significant adverse findings of a particular component will result in an inspection of all such components of that engine to determine any adverse trends. Favorable findings will result in reassembly of the engine for service.

2. Daily Frequency - To be performed once per day.

3. Monthly Frequency - To be performed once in a month; normally during, before, or after test run per plant Technical Specifications.

4. EOC (End of Cycle) - To be performed once during outage for refueling.

5. Alternate EOC - To be performed once every other outage for refueling.

6. Five Years - To be performed once at the EOC occurring nearest to the end of a recurring five-year period or at the EOC midway between the one time EOC 2 inspections and the first overhaul inspection and subsequently midway between each overhaul.

7. As Required - To be performed as often as good maintenance, site procedures, manufacturer's recommendations, or experience dictate as determined by site personnel.

8. Maintenance - Monitoring and/or surveillance on a periodic frequency to assure the component will perform its intended function in a safe reliable manner.

9. Accessible - Any item on which the required function can be performed without disassembly of an engine component. Removal of defined access cover is <u>not</u> considered disassembly.

10. Appropriate NDE - Nondestructive examination selected by site personnel that is most suitable to obtain the information sought by an individual inspection item; choice of NDE shall be made to assure that the technique will detect indications consistent with the acceptance criteria.

TABLE 1

Diesel Engine Operating Surveillance Parameters and Frequency

	COMPONENT	FREQUENCY
1)	Lube Oil Inlet Pressure to Engine	Log hourly
2)	Lube Oil Filter Differential Pressure	Log hourly
3)	Lube Oil Temperature (engine inlet and outlet)	Log hourly
4)	Lube Oil Sump Level	Log hourly
5)	Turbocharger Oil Pressure	Log hourly
6)	Fuel Oil Filter Differential Pressure	Log hourly
7)	Fuel Oil to Engine Pressure	Log hourly
8)	Fuel Oil Day Tank Level	Check hourly
9)	Jacket Water Pressure (engine inlet)	Log hourly
10)	Jacket Water Temperature (in, out)	Log hourly
11)	Engine Cylinder Temperature Exhaust - All (if temperature in any one cylinder exceeds 1050°, refer to MP-022/023 Item 7).	Log hourly
12)	Manifold Air Temperature (RB, LB for DSRV Engines)	Log hourly
13)	Manifold Air Pressure (RB, LB for DSRV Engines)	Log hourly
14)	Starting Air Pressure (RB, LB for DSRV Engines)	Check hourly
15)	Crankcase Vacuum	Log hourly
16)	Engine Speed	Log hourly
17)	Hour Meter	Log hourly
18)	Kilowatt Load	Log hourly
19)	Visual Inspection for Leaks, etc.	Check hourly

TABLE 2

Diesel Engine Standby Surveillance Parameters and Frequency

	COMPONENT	FREQUENCY
1)	Lube Oil Temperature (in, out)	Log daily
2)	Lube Oil Sump Level	Log daily
3)	Check Operation of Lube Oil Keep-Warm Pump Motor	Daily
4)	Monitor Lube Oil Keep-Warm Strainer and/or Filter Differential Pressure	Daily
5)	Perform a visual inspection for leakage of the Lube Oil Heat Exchanger. Verify that no leakage through the leak-off ports of the lantern ring is present.	Daily
6)	Fuel Oil Day Tank Level	Log daily
7)	Jacket Water Temperature (in, out)	Log daily
8)	Perform a visual inspection for leakage at packing for Jacket Water Heat Exchanger whenever the engine is in the emergency STANDBY mode. Verify that no leakage through the leak-off ports of the lantern ring is present.	Daily
9)	Verify proper governor oil level	Daily
10)	Verify proper oil level of generator pedestal bearing	Daily
11)	Starting Air Pressure	Log daily
12)	Drain air receiver float traps and/or drain Starting Air Storage Tank and monitor the quantity of moisture produced. If quantity of moisture is excessive, correct immediately.	Daily
13)	Check Operation of Compressor Air Traps	Daily
14)	Test Annunciators	Before Engine Operation
15)	Check Alarm Clear	Before Engine Operation

TABLE 2 (cont'd)

Diesel Engine Standby Surveillance Parameters and Frequency

	COMPONENT	FREQUENCY
16)	Inspect for Leaks	Daily
17)	Visually inspect intercooler for external leaks including intake manifold drain connection.	Daily

APPENDIX A

PART B

TDI
OWNERS GROUP

APPENDIX - II

GENERIC MAINTENANCE MATRIX

PART B

PHASE I COMPONENTS

GENERIC MAINTENANCE MATRIX - PHASE I

Component Number	Component Identification	PM Recommendation	Monthly	EOC	Alt EOC	5 Year	Overhaul	Comments
MP-022/23	Turbocharger	1. Measure vibration and check with baseline data.		X				To be accomplished after obtaining stable exhaust temperature conditions.
		2. Inspect impeller/diffuser and clean if necessary.				X		
		3. Measure rotor end play (axial clearance) to identify trends of increasing clearance (i.e., thrust bearing degradation).		X				Review thrust bearing axial clearances after inspection to determine if a trend exists. Any trend toward increasing axial clearance could signify thrust bearing degradation.
		4. Perform visual and blue check inspections of the thrust bearing.				X		Note: Thrust bearing inspection should also be performed after experiencing each 40 nonprelubed (automatic) fast starts. In addition, a one-time inspection should be completed after the first 100 engine starts.
		5. Disassemble, inspect, and refurbish.				X		Note: During reassembly, ensure that capscrews are properly installed with the recommended torque. If QR inspection was performed prior to accumulating significant hours (i.e., the number of hours accumulated during plant preoperational testing, approximately 100 hours), the turbochargers should be reinspected at the next EOC.
		6. The nozzle ring components and inlet guide vanes should be visually inspected for missing parts or parts showing distress. If such conditions are				X		Or perform a visual inspection on one turbocharger per nuclear unit at each EOC.

Component Number	Component Identification	PM Recommendation	Monthly	EOC	Alt EOC	5 Year	Overhaul	Comments
		noted, the entire ring assembly should be replaced.						Any turbocharger in which nozzle ring anomalies are found is to be reinspected at the next EOC. Note: Discontinue inspection with appropriate redesign.
		7. Monitor inlet temperature to ensure gas temperature does not exceed manufacturer's recommendation of 1200°F if exhaust temperature for any cylinder exceeds 1050°F (Refr: Table I).						Monitoring may be performed using permanent in-line thermocouple, strap-on thermocouple, heat gun, or other suitable means that has been appropriately tested and calibrated per plant procedures. Note: Also perform monitoring any time the engine operates in an unbalanced condition.
02-305A	Base Assembly	1. Perform a visual inspection of the base. The inspection should include the areas adjacent to the nut pockets of each bearing saddle and be conducted after a thorough wipe down of the surfaces, using good lighting.					X	Note: Any cracks detected must be investigated further before the engine is allowed to return to service. The mating surfaces of the base and cap shall be thoroughly cleaned with solvent before any reassembly. Perform on EOC basis for 3 cycles, then overhaul provided there are satisfactory results. Note: 3 EOC inspections may be eliminated by performing a metal analysis to confirm consistent to class 40 grey iron requirements; performing analysis does not eliminate need for overhaul inspections.

GENERIC MAINTENANCE MATRIX - PHASE I

Component Number	Component Identification	PM Recommendation	Monthly	EOC	Alt EOC	5 Year	Overhaul	Comments
02-305C	Main Bearing Caps - Studs and Nuts	1. The mating surfaces at the bearing cap/saddle interface should be inspected when disassembled to ensure the absence of surface imperfections that might prevent tight boltup. Note: Upon removal of bearing caps, clean mating surfaces with a solvent prior to reassembly of the caps to the base.						
02-310A	Crankshaft	See site specific recommendations						
02-315A	Cylinder Block	See site specific recommendations						
02-315C	Cylinder Liners	1. Perform a visual inspection of liners for progressive wear.						To be performed for one EOC following piston removal; then discontinue until next piston removal. Boroscopic inspection is acceptable if heads are not removed. Complete TDI Inspection and Maintenance Record Form No. 315-1-1 as applicable, TDI Instruction Manual, Volume I, Section 6.
02-340A/B	Connecting Rods, Bushings and Bearing Shells (Generic)	1. Inspect and measure all connecting rod bearing shells to verify lube oil maintenance, which affects wear rate.					X	Complete TDI Inspection and Maintenance Record Form No. 340-1-1 as applicable, TDI Instruction Manual, Volume I, Section 6, appendix III for clearance values. Perform inspection at 5 years, on items accessible, consistent with item 2 of this component.

GENERIC MAINTENANCE MATRIX - PHASE I

Component Number	Component Identification	PM Recommendation	Monthly	EOC	Alt EOC	5 Year	Overhaul	Comments
		2. Inspect and measure the connecting rods. Note: Perform inspection and measure four connecting rods for DSRVs and two for DSRs at random at one time 5-year inspection.					X	Complete TDI Inspection Maintenance Record Form No. 340-2-1, -2 as applicable, TDI Instruction Manual, Volume I, Section 6.
		3. Perform an x-ray examination on all replacement bearing shells to acceptance criteria developed by Owners Group Technical Staff.						This is to be performed prior to installation of any replacement bearing shells as required.
		4. All connecting rod bolts, nuts, and washers should be visually inspected, and damaged parts should be replaced. The bolts should be MT inspected to verify the continued absence of cracking. No detectable cracks should be allowed at the root of the threads.					X	Perform inspection at 5 years, on items accessible, consistent with Item 2 of this component.
		5. During any disassembly that exposes the inside diameter of a rod-eye (piston pin) bushing, the surface of the bushing should be LP inspected to verify the continued absence of linear indications in the heavily loaded zone width +/-15 degrees of the bottom dead-center position.						Perform inspection, as required and on items accessible, consistent with Item 2 of this component.
02-340 A/B DSRV's only	Connecting Rods, Bushings and Bearing Shells	6. Measure the clearance between the link pin and link rod. This clearance should be zero; i.e.,						To be performed at each reassembly of link pin to link rod.

GENERIC MAINTENANCE MATRIX - PHASE I

Component Number	Component Identification	PM Recommendation	Monthly	EOC	Alt EOC	5 Year	Overhaul	Comments
		no measurable clearance when the specified bolt torque of 1,050 ft-lbs is applied.						
		7. At the overhaul, visually inspect the rack teeth surfaces for signs of fretting and at one time 5-year inspection for rods disassembled.					X	
		8. Inspect mating surfaces to verify that the minimum manufacturers' recommended percent contact surface is available.						To be performed once for new and/or replacement parts.
		9. If connecting rod bolt stretch was measured ultrasonically during reassembly following the preservice inspection, the lengths of the two pair of bolts above the crankpin should be remeasured ultrasonically before the link rod box is disassembled. If ultrasonic measurement was not previously used, begin use at next inspection that accesses the connecting rods. Measure bolt stretch before disassembly.					X	Also to be performed at any time the connecting rod is disassembled. Perform inspection at 5 years, on items accessible, consistent with Item 2 of this component.
		10. All connecting rod bolts should be visually inspected for thread damage (galling) and the two pairs of connecting rod bolts above the crankpin should be MT inspected to verify the absence of cracking. All washers used with the bolts should be examined visually for signs of galling or cracking and replaced if damaged. If prestressor package is installed, this item does <u>not</u> apply.					X	Also to be performed at any time the connecting rod is disassembled. Perform inspection at 5 years, on items accessible, consistent with Item 2 of this component.

GENERIC MAINTENANCE MATRIX - PHASE I

Component Number	Component Identification	PM Recommendation	Monthly	EOC	Alt EOC	5 Year	Overhaul	Comments
		11. A visual inspection should be performed of all external surfaces of the link rod box to verify the absence of any signs of service-induced distress					X	Also to be performed at any time the connecting rod is disassembled. Perform inspection at 5 years, on items accessible, consistent with Item 2 of this component.
		12. All of the bolt holes in the link rod box should be inspected for thread damage (galling) or other signs of abnormalities. Bolt holes subject to the highest stresses (the pair immediately above the crankpin) should be examined with an appropriate non-destructive method to verify the absence of cracking. Any indications should be recorded for evaluation and corrective action. If prestressor package is installed, this item does <u>not</u> apply.					X	Also to be performed at any time the connecting rod is disassembled. Perform inspection at 5 years, on items accessible, consistent with Item 2 of this component
02-341A	Pistons	1. Inspect and measure skirt and piston pin. This item assumes that AE skirts are installed. For other types, see site-specific recommendations.					X	Complete TDI Inspection and Maintenance Report Form No. 341-1-1 as applicable, TDI Instruction Manual, Volume I, Section 6. Use Volume I, Section 8, Appendix III for clearances values. To be performed at 5-year interval on sampling basis consistent with Component 02-340A/B-Connecting Rods.
02-360A	Cylinder Head	1. Visually inspect cylinder heads (all cylinders).					X	Complete TDI Inspection and Maintenance Record Form No. 360-1-1 as applicable, TDI Instruction Manual, Volume I, Section 6 - one sheet for each head. To be performed at 5-year interval on sampling basis consistent with Component 02-340 A/B - Connecting Rods.

GENERIC MAINTENANCE MATRIX - PHASE I

Component Number	Component Identification	PM Recommendation	Monthly	EOC	Alt EOC	5 Year	Overhaul	Comments
		2. Record cold compression pressures and maximum firing pressures.		X				If so indicated - remove cylinder heads, grind valves, and reseat. Refr: TDI Instruction Manual, Volume I, Section 6.
		3. Blow-over the engine at least 4 hours but not more than 8 hours after engine shutdown. The cylinder cocks should be open for detection of water leakage into the cylinders. A second air roll should be performed in the same manner approximately 24 hours after engine shutdown. In addition, the engine should be air rolled shortly before any planned start.						In the event water is detected, the cylinder head should be replaced or returned to the vendor for repair. Delete post-run air roll requirements for engines with Group III heads after one cycle with positive inspection results.
		4. Visually inspect the area around the fuel injection port on each cylinder head during the normal monthly run for signs of leakage.	X					If water leakage is detected, the head(s) should be replaced.
02-365C	Fuel Injection Tubing	1. Check tubing for leaks at compression fittings.	X					All fuel oil leak inspections to be performed while the engine is running or whenever the compression fittings have been disturbed.
		2. Visually inspect tubing lengths for fuel oil leaks or cracks if tubing is unshrouded. If shrouded, fuel oil leakage can be detected at the leak-off ports in the base nuts, which are provided for this purpose, or by annunciator if so equipped.	X					Fitting inspection for leaks to be performed at engine operation following shutdown. Subsequent inspections to be performed periodically as indicated. Unshrouded tubing, used as replacement, should be fully inspected consistent with FaAA NDE Procedure 11.10 prior to bending.

GENERIC MAINTENANCE MATRIX - PHASE I

Component Number	Component Identification	PM Recommendation	Monthly	EOC	Alt EOC	5 Year	Overhaul	Comments
02-390C	Push Rods	1. Each push rod of the forged-head design should be inspected by liquid penetrant prior to installation or, if installed, at each overhaul. This should be repeated, until it has been determined by 750 hours of operation at the load level used for surveillance testing that the push rod will not develop service-induced cracks. Push rods confirmed in this way need be examined only visually at subsequent overhauls. Push rods of the forged-head design exhibiting cracks larger than 0.25 inch should be replaced, preferably with push rods of the friction-welded design. Each forged-head rod should also be visually inspected one time to confirm that the head was fully inserted in the tube prior to welding. Lower					X	Refr: PNL-5600
		2. Each push rod of the friction-welded design should be inspected initially by liquid penetrant. If this initial inspection was not performed prior to placing the push rods in service, it should be performed at the first overhaul. If the friction-welded push rod has been previously inspected by liquid penetrant, then visual examination will suffice for future inspections. All friction-welded push rods with cracks should be replaced, preferably with push rods of the same design.					X	Refr: PNL-5600. If initial inspection was not performed, perform on sampling basis at 5-year inspection consistent with Component 340A/B - Connecting Rods.

GENERIC MAINTENANCE MATRIX - PHASE I

Component Number	Component Identification	PM Recommendation	Monthly	EOC	Alt EOC	5 Year	Overhaul	Comments
02-390G	Rocker Arm Capscrews, Drive Studs (Pop Rivets)	1. Verify capscrew torque values during QR inspections. If not performed at QR, verify at next EOC, then as required at reassembly.						Use TDI Instruction Manual, Volume I, Section 8, Appendix IV for proper torque values.
		2. Verify that rocker arm drive studs are intact and tight during QR inspection or EOC1, then as required at reassembly.						
02-425A	Jacket Water Pump - Gear	1. Visually inspect jacket water pump gear for chipped or broken teeth, excessive wear, pitting or other abnormal conditions.				X		Any abnormal situations or indications of progressive pitting should be reported for an engineering evaluation. For engines with less than 750 hours, also inspect by EOC2.
		2. Check the key to keyway interface for a tight fit on both the pump shaft to impeller and the spline to pump shaft during pump reassembly. At next disassembly, verify impeller is one piece (i.e., without a bore insert). If it is not a one-piece impeller, replace.					X	This along with the drive fit of the impeller onto the shaft will preclude past problems where relative motion between shaft and impeller caused fretting and upset of the keyway sides.
		3. It is recommended that the castle nut that drives the external spline on its taper have minimum and maximum torque values of 120 ft-lbs and 660 ft-lbs, respectively for DSRVs and a maximum torque value of 77 ft-lbs for DSRs.						Torque valves will be checked each time castle nut is reassembled.

SITE-SPECIFIC MAINTENANCE MATRIX

Component Number	Component Identification	PM Recommendation	Monthly	EOC	Alt EOC	5 Year	Overhaul	Comments
02-310A	Crankshaft	1. Measure and record crankshaft web deflections (hot and cold).		X				Complete TDI Inspection and Maintenance Record Form No. 310-1-1 as applicable, TDI Instruction Manual, Volume 1, Section 6. Refr: TDI Instruction Manual, Volume 1, Maintenance Schedule.
		2. Examine the fillets and oil holes of three main bearing journals (4, 6, & 8) using LP. If indications are evident, a more thorough examination should be made using appropriate NDE methods.					X	Also to be performed once at 5 years. Refr: PNL-5600.
		3. Examine the fillets and oil holes in three of the crankpin journals (choose 3 from Nos. 3 through 8 inclusive) using LP. If indications are evident, a more thorough examination should be made using appropriate NDE methods.					X	Also to be performed once at 5 years. Refr: PNL-5600.
		4. Measure diameter of crankpin journals.					X	Complete TDI Inspection and Maintenance Record Form No. 310-3-1 as applicable, TDI Instruction Manual, Volume 1, Section 6. Aso perform inspection at 5 years, on items accessible, consistent with this component and Component 02-340A/B.
		5. Analyze the trends of cylinder pressure and temperature measurements to detect imbalances.		X				If an engine operates in a severely unbalanced condition, reinspect the oil holes for fatigue cracks wihin a time-frame determined by the utility considering the particular circumstances of the abnormal operation. Refr: PNL-5600.

SITE-SPECIFIC MAINTENANCE MATRIX

Component Number	Component Identification	PM Recommendation	Monthly	EOC	Alt EOC	5 Year	Overhaul	Comments
		Note: To avoid the effect of the 4th order resonance, steady normal-loaded operation at speeds more than a few rpm below the rated speed of 450 rpm should be avoided. Appropriate precautions should be taken to prevent sustained engine operation with significant cylinder imbalance. Lower speeds for testing and break-in are permissible. Avoid resonance frequencies.						Refr: PNL-5600.

SITE-SPECIFIC MAINTENANCE MATRIX

Component Number	Component Identification	PM Recommendation	Monthly	EOC	Alt EOC	5 Year	Overhaul	Comments
02-315A	Cylinder Block	1. Perform inspections per DR/QR Report 02-315A.						Inspections based on cumulative engine hours in conjunction with FaAA reports FaAA-84-9-11 and SP-84-6-12(j).
		2. Perform visual inspection for cracks. Note: Visual inspection not required if an appropriate NDE is performed.					X	

APPENDIX B

APPENDIX B

RESULTS OF INSPECTION FOR TDI DIESEL GENERATOR PHASE I COMPONENTS

COMPONENT NAME	COMPONENT NO.	PM RECOMMENDATION NO.	NO. OF INSPECTIONS	RESULTS AND COMMENTS
TURBOCHARGER	MP 022/023	1	Note 1	No problems found.
		2	50	No problems found.
		3	87	No problems found.
		4	47	No problems found. Some normal bearing wear has been reported. This wear has been dispositioned by the vendor as being within acceptable limits.
		5	47	No problems found.
		6	60	No major problems found. Vogtle and Grand Gulf have reported broken or missing bolts passing through the rotating element without identifiable degradation. Vogtle, Grand Gulf and Catawba have reported missing stationary vanes without identifiable degradation. Missing or damaged items were replaced.
		7	Note 2	Performed on each test run.

Note 1: Inspections performed monthly. The number of inspections are greater than 200.

Note 2: Performed on multiple occassions during test runs. A large data base exists.

Reference Attachment 1 for Phase I Components

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RESULTS OF INSPECTION FOR TDI
DIESEL GENERATOR PHASE I COMPONENTS

COMPONENT NAME	COMPONENT NO.	PM RECOMMENDATION NO.	NO. OF INSPECTIONS	RESULTS AND COMMENTS
BASE ASSEMBLY	02-305A	1	43	No problems found.
Reference Attachment 1 for Phase I Components				Rev 1 4/19/93

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RESULTS OF INSPECTION FOR TDI
DIESEL GENERATOR PHASE I COMPONENTS

COMPONENT NAME	COMPONENT NO.	PM RECOMMENDATION NO.	NO. OF INSPECTIONS	RESULTS AND COMMENTS
MAIN BEARING CAPS - STUDS AND NUTS	02-305C	1	28	No findings on bearing caps. Note that inspections are based upon the number of bearing caps examined. 1
				Perry has reported one shell with rolled edges due to contact with counter weight. Bearing performance was determined to be satisfactory and the reported item corrected.

Reference Attachment 1 for Phase I Components

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DIESEL GENERATOR PHASE I COMPONENTS

COMPONENT NAME	COMPONENT NO.	PM RECOMMENDATION NO.	NO. OF INSPECTIONS	RESULTS AND COMMENTS
CRANKSHAFT	02-310A	1	188	No problems found. Inspection is number of hot and cold deflection measurements taken.
		2	67	Inspection is number of oil holes inspected. No problems found. Upon bearing rollout to perform inspections, River Bend has experienced minor cavitation, including pitting on bearing surfaces. This was evaluated and dispositioned as not a problem. The bearings in question had performed their function and could continue to operate withouy adverse effects. Bearings were replaced as good engineering practice.
		3	42	No problems found. Inspection is number of fillet and oil holes inspected.
		4	35	No problems found. Inspection is number of crankpin journals measured.
		5	Note 1	No problems found.

Note 1: Inspections performed monthly. The number of inspections are greater than 200.

Reference Attachment 1 for Phase I Components

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RESULTS OF INSPECTION FOR TDI
DIESEL GENERATOR PHASE I COMPONENTS

COMPONENT NAME	COMPONENT NO.	PM RECOMMENDATION NO.	NO. OF INSPECTIONS	RESULTS AND COMMENTS
CYLINDER BLOCK	02-315A	1	105	No problems found. Inspection is related to number of areas inspected under individual heads when removed.
		2	159	No problems found. Number of inspections include inspections made by several utilities during operation.
Reference Attachment 1 for Phase I Components				Rev 1 4/19/93

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RESULTS OF INSPECTION FOR TDI
DIESEL GENERATOR PHASE I COMPONENTS

COMPONENT NAME	COMPONENT NO.	PM RECOMMENDATION NO.	NO. OF INSPECTIONS	RESULTS AND COMMENTS
CYLINDER LINERS	02-315C		512	No problems found. Number of inspections represent number of liners inspected. Vogtle has reported light and moderate scratches with bright spots and carbon build-up. This has been evaluated and dispositioned as acceptable. Grand Gulf has found indications of porosity. The liners performed as designed and were dispositioned as acceptable, but were replaced as good engineering practice.

Reference Attachment 1 for Phase I Components

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RESULTS OF INSPECTION FOR TDI
DIESEL GENERATOR PHASE I COMPONENTS

COMPONENT NAME	COMPONENT NO.	PM RECOMMENDATION NO.	NO. OF INSPECTIONS	RESULTS AND COMMENTS
CONNECTING RODS, BUSHINGS AND BEARING SHELLS (GENERIC)	02-340A/B	1	42	No problems found. 1 Inspections indicate the number of connecting rod bearings. River Bend has reported some cavatiation induced pitting. The bearings remained capable of performing as designed, but were replaced as good engineering practice. The oil analysis did not identify bearing material in the lube oil prior to replacement. 1 Vogtle has found three shells with evident wear and/or indications. These shells were evaluated and dispositioned as acceptable. They were replaced as good engineering judgement.
		2	36	No problems found. Inspection is the number of connecting rods examined.
		3	NA	See Referenced submittal to NRC, Appendix C & D 1
		4	89	No problems found. Inspection is the number of connecting rods examined.
		5	34	No problems found. Inspection is the number of rod-eye bushings examined.
		6	71	No problems found. Inspection is the number of connecting rods examined.
Reference Attachment 1 for Phase I Components				Rev 1 4/19/93

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RESULTS OF INSPECTION FOR TDI
DIESEL GENERATOR PHASE I COMPONENTS

COMPONENT NAME	COMPONENT NO.	PM RECOMMENDATION NO.	NO. OF INSPECTIONS	RESULTS AND COMMENTS
CONNECTING RODS, BUSHINGS AND BEARING SHELLS (GENERIC)	02-340A/B	7	20	No problems found. Inspection is the number of rack teeth examined.
		8	73	No problems found. Inspection is the number of sets of rod teeth examined (required for new or replacement rods).
		9	296	No problems found. Inspection is the number of connecting rods examined.
		10	20	No problems found. Inspection is the number of connecting rods examined. 1
		11	20	No additional problems found. 1
		12	20	No problems found. Inspection is the number of connecting rods examined. Vogtle has found 1 indication in a hole. It was evaluated and dispositioned as acceptable. The rod was replaced as good engineering practice. 1

Reference Attachment 1 for Phase I Components

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RESULTS OF INSPECTION FOR TDI
DIESEL GENERATOR PHASE I COMPONENTS

COMPONENT NAME	COMPONENT NO.	PM RECOMMENDATION NO.	NO. OF INSPECTIONS	RESULTS AND COMMENTS
PISTONS	02-341A	1	39	No problems found. Inspection is the number of pistons examined. Grand Gulf has found 3 piston pins and plugs to be slightly loose. This was evaluated and dispositioned as acceptable. The plugs were replaced as good engineering practice.
Referencs Attachment 1 for Phase I Components				Rev 1 4/19/93

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RESULTS OF INSPECTION FOR TDI
DIESEL GENERATOR PHASE I COMPONENTS

COMPONENT NAME	COMPONENT NO.	PM RECOMMENDATION NO.	NO. OF INSPECTIONS	RESULTS AND COMMENTS
CYLINDER HEAD	02-360A	1	151	No problems found. Inspection is the number of heads examined. Vogtle has found minor pitting and nicks in 4 valves. This was evaluated and dispositioned as acceptable. Perry has found 2 exhaust valve seat cuts. Performance was not effected. This was evaluated and dispositioned as acceptable. The heads were replaced as good engineering practice. River Bend has found problems with swivel pads. This is discussed in Section 3.12
		2	Note 1	No problems found.
		3	Note 2	No problems found. Some mist has been detected on several ocassions, leading to an in-depth investigation as to the cause. The results are incorporated in Section 3.12 and PM Recommendation No. 1
		4	Note 3	Inspection performed each run. No problems found
Note 1: Inspection performed each EOC and more frequently by several utilities. This inspection collectively amounts to greater than 200 inspections.				
Note 2: Inspection performed prior to each start and collectively amounts to greater than 200 inspections.				
Note 3: Inspections performed monthly. The number of inspections are greater than 200.				
Reference Attachment 1 for Phase I Components				Rev 1 4/19/93

APPENDIX B

RESULTS OF INSPECTION FOR TDI DIESEL GENERATOR PHASE I COMPONENTS

COMPONENT NAME	COMPONENT NO.	PM RECOMMENDATION NO.	NO. OF INSPECTIONS	RESULTS AND COMMENTS
FUEL INJECTION TUBING	02-365C	1	Note 1	No problems found. Minor fitting leaks have been found and repairs are made as leaks are discovered. Catawba has examined 1 tubing failure of unshrouded tubing due to vibrations. River Bend has experienced 1 failure of the shrouded tubing due to the fuel injection pump base cap screws failing. The tubing was replaced and the engine restored to service. Root cause was evaluated and dispositioned as not being a problem.
		2	Note 1	Same as for PM Recommendation No. 1

Note 1: Inspections performed monthly. The number of inspections are greater than 200.

Reference Attachment 1 for Phase I Components

Rev 1 4/19/93

APPENDIX B

RESULTS OF INSPECTION FOR TDI
DIESEL GENERATOR PHASE I COMPONENTS

COMPONENT NAME	COMPONENT NO.	PM RECOMMENDATION NO.	NO. OF INSPECTIONS	RESULTS AND COMMENTS
PUSH RODS	02-390C	1	NA	Push rods of this design are not in service.
		2	940	Inspection is the number of push rods examined. No problems found.

Reference Attachment 1 for Phase I Components

Rev 1 4/19/93

APPENDIX B

RESULTS OF INSPECTION FOR TDI
DIESEL GENERATOR PHASE I COMPONENTS

COMPONENT NAME	COMPONENT NO.	PM RECOMMENDATION NO.	NO. OF INSPECTIONS	RESULTS AND COMMENTS
ROCKER ARM CAPSCREWS, DRIVE STUDS (POP RIVETS)	02-390G	1	551	Inspection is of rocker arm assemblies. No problems found.
		2	551	No problems found.
				Inspection is for rocker arm assemblies. Two pop rivets have been found missing. One each on the River Bend EDGs. Result was no degradation in EDG operability since oil flow continued to the required locations. Grand Gulf has found bearing wear. An evaluation has dispositioned this as normal. However, they were replaced based on good engineering judgement.
Reference Attachment 1 for Phase I Components				Rev 1 4/19/93

APPENDIX B

RESULTS OF INSPECTION FOR TDI
DIESEL GENERATOR PHASE I COMPONENTS

COMPONENT NAME	COMPONENT NO.	PM RECOMMENDATION NO.	NO. OF INSPECTIONS	RESULTS AND COMMENTS
JACKET WATER PUMP - GEAR	02-425A	1	22	No significant problems found.
		2	8	Inspections are for the number of verifications. No problems found.
		3	1	Inspections are for the number of verifications. No problems found.

Reference Attachment 1 for Phase I Components

Rev 1 4/19/93

APPENDIX C

DUKE ENGINEERING & SERVICES, INC.

230 South Tryon St.
P.O. Box 1004
Charlotte, NC 28201-1004

Bus (704) 3
Fax (704) 37

October 31, 1991

Mr. P. Om Chopra
Office of Nuclear Reactor Regulation
Electrical Systems Branch (MS 7 E4)
U. S. Nuclear Regulatory Commission
Washington, DC 20555

Re: Cooper-Enterprise Clearinghouse Group
Diesel Generators
Position Paper on Radiograph Requirements
for Connecting Rod Bearing Shells
File: MTS-4086

Dear Mr. Chopra:

Enclosed is Cooper-Enterprise Clearinghouse Group's position concerning the current radiographic examination requirement for the diesel generator's connecting rod bearing shells as detailed in Appendix II of the Design Review/Qualification Revalidation (DR/QR) Report. The position paper provides the necessary technical justification to permit elimination of requirements to inspect replacement bearings shells by radiographic techniques.

The Clearinghouse Group is requesting relief from the radiographic examination requirements because the bearings supplied by Cooper Industries are presently being manufactured by Federal-Mogul, rather than the former manufacturer/supplier, ALCOA. Federal-Mogul manufactures their bearing using a centrifuge process,a more advanced method than the static mold process used by ALCOA. The centrifuge process eliminates the potential for void formation and therefore radiographic examination is not required.

The Clearinghouse Group requests you review the enclosed document and based upon the technical justification provided, determine on a generic basis, that the current radiographic requirements are not necessary.

Response to this issue by January 31, 1992 will be greatly appreciated by the Clearinghouse and the individual utilities members. Should you have questions, please direct them to Rick Deese at (704) 875-4065.

Very truly yours,

RDBroome

R. D. Broome
Project Manager
Cooper-Enterprise Clearinghouse
Duke Engineering & Services, Inc.

J. B. George
Chairperson
Cooper-Enterprise Clearinghouse
TU Electric

RDB/VMA/100991

Enclosure

cc: E. B. Tomlison (NRC)
Clearinghouse Representatives
R. J. Deese

POSITION PAPER FOR RADIOGRAPHIC EXAMINATION OF CONNECTING ROD BEARING SHELLS (02-340B) FOR ENTERPRISE DSR-8, DSRV-16 AND DSRV-20 ENGINES

Purpose

The purpose of this position paper is to provide sufficient technical justification to permit the elimination of the DR/QR Appendix II requirement to inspect replacement bearing shells by radiographic techniques.

Background

During the period of 1983-1985, thirteen utilities formed the TDI Owners Group and contracted Duke Management and Technical Services, Inc. (now Duke Engineering & Services, Inc.) to perform a Design Review and Quality Revalidation (DR/QR) of the TDI engines following the crankshaft failure at Shoreham. A portion of this review focused on the connecting rod bearing shells. The experience based review of this component revealed a very small amount of bearing failures. These failures were attributed to two causes: (1) inadequate clamping force in the connecting rod assembly due to inadequate pre-load of the connecting rod bolts, and (2) potential voids and/or impurities induced into the bearing during the casting process. These two items were corrected by: (1) increasing connecting rod bolt pre-load, and (2) performing (NDE) (radiography) of the bearing shells to detect voids or impurities.

Technical Discussion

The original bearings reviewed and supplied by TDI were cast by ALCOA in static molds. These castings were taken by TDI, machined, electroplated with babbit, and then re-machined to final tolerances. Cooper Enterprise (formerly TDI) has informed the nuclear customers that they will begin supplying bearings purchased from a sub-supplier, Federal Mogul Corporation. These bearings are cast via a centrifuge process that is superior to using a static mold in that the centrifuge assures a more uniform placement of equal density material.

Attachment 1 from Federal Mogul offers more details on this issue.

Material Testing

Federal Mogul performed radiographic inspections of bearing shells cast by the centrifuge techniques. These radiographs exhibited dark spots or "ghosts". Several bearings containing these indications were sectioned and metallurgically examined. These images were the result of either (1) material with columnar grains as opposed to equi-axed or (2) slightly lower tin content in the columnar grain areas. The results of the metallurgical examinations concludee that the metal in these areas is equal to the remaining material in mechanical properties; and therefore the shells will perform as required.

Cooper Enterprise has purchased and installed these bearings in several non-nuclear engines. Theses engines have accumulated thousands of operating hours without failure.

Recommendation

Due to the manufacturing change that produces quality casting and favorable operating history, it is recommended that the requirement to radiograph connecting rod bearing shells be deleted. Note that Cooper Enterprise concurs with this recommendation (see Attachment 2).

FEDERAL-MOGUL TECHNICAL CENTER
Engine and Transmission Products
April 16, 1991 #91-04 Page 1

ATTACHMENT 1

Cooper Energy P/N 02-340-04-AG: Bearings Rejected by Radiography

Abstract

Bearings rejected by Cooper Energy (25 pcs.) were examined using metallography, microhardness, and SEM/EDS analysis. Conclusion is that dark spots in radiograph (normally indicative of lower density material, porosity, or oxide inclusion) are in this case due to one or both of two possible causes: either (1) small patches of material with columnar grains as opposed to equiaxed, or (2) slightly lower tin content in these columnar grain areas. Consultation with a radiographic expert confirm that the columnar grains can cause such an effect in the radiograph. All metallurgical tests indicate that this metal is equal in mechanical properties to the equiaxed grains, and therefore predict that parts will perform acceptably in service.

Copy to: B. Bridgham, D. Pazuk, A. Sparks, R. Moore, D. Jackson, R. Poehler, G. Pratt, J. Jones, H. Gibson, W. Cook, Ann Arbor File

File Under: B-850, Mooresville, Cooper Energy

Introduction

Cooper Energy purchases heavy wall B-850 bearings from Mooresville for general use. When required for special applications, the bearings are inspected by radiography, prior to use, by an outside lab, on behalf of Cooper. As of April 11, 1991, Cooper reported to Mooresville that they have approximately 25 bearings which they are rejecting due to indications found in radiography. The defect in radiography appears as a fuzzy dark area on the radiographic film. The dark spots appear sporadically, but are more prevalent on one half of the bearing than the other (in other words, the prevalence differs between the top and bottom half of the part as cast.) Unfortunately, there is no way to determine once the part is machined, which half was the top and which was the bottom. Normally a dark patch in the radiograph would indicate a low-density area such as porosity, oxide inclusion, or lack of high density phase (in this case tin).

Discussion

On April 11, a team consisting of B. Bridgham, W. Cook, H. Gibson and the writer attempted to determine the cause of the dark spots. What we found was that the dark spots corresponded to small areas of columnar grains in the material. Figures 1, 2 and 3 show cross sections of the bearing wall, heavily etched with Keller's etch, to reveal the difference in grain structure. In all cases, the columnar grains appear near the ID of the bearing.

However, it should be noted that even though it is near the ID of the part it is closer to the OD than to the ID of the unfinished casting, as there is far more material removed from the ID than the OD of the casting during bearing manufacture. Figures 4 and 5 show the actual grain structure, as heavily Keller's etched. It can be seen that the columnar grains are much longer than the equiaxed grains in the lengthwise direction, but possibly a bit smaller in the short direction. An attempt was made to characterize the difference between the two structures.

SEM/EDS studies reveal very little difference in chemical composition between the two regions. Tin content, the most likely material to segregate and cause a difference in density, was found (semi-quantitatively) to be 5.5% in the equiaxed area and 5.1% in the columnar region. This small difference probably does not fully explain the dark spot in the radiograph. However, in a paper entitled *Realtime X-ray Reveals Bonus Information* (attached) by Mr. James L. Wheelis of Magnaflux Corporation (Chicago Office), it is described how the abnormalities in radiographs (he terms them 'Ghost indications') similar to those we see here can be caused by differences in grain structure. It is not known which of these two effects contributes more to the observed dark clouds in the radiograph.

Microhardness (Hv 50 gram) traces were made across the columnar area. A panoramic photo showing the actual indentations is seen in Figure 6. Results of the microhardness tests are as follows:

Equiaxed		Columnar		Equiaxed	
Position	Hardness, Hv	Position	Hardness, Hv	Position	Hardness, Hv
1	62.7	7	63.7	11	N/A*
2	68.3	8	67.0	12	53.2
3	57.5	9	72.5	13	71.9
4	73.8	10	76.3		
5	76.5				
6	64.0			*Unsuccessful test	

Note: All readings are within specification of 50-75 Hv.

Furthermore, one microhardness in each area was taken with the 1 kg load. This load would be less subject to extremely localized aberrations such as grain boundaries and microporosity. Results are as follows:

Equiaxed:	Hv 60.3
Elongated:	Hv 58.4

The difference between these two numbers is deemed to be insignificant.

In this study, no definite reason for the areas of different grain structures could be ascertained. The most plausible explanation is that the small manifestations of columnar grains represent small parcels of material which froze either on the bottom of the mold or on the sidewalls prior to the beginning of mold rotation. When the mold began rotating, the small pieces of frozen material (with columnar structure, since it froze in contact with the cold surface) was washed away and ended up in its final resting point approximately 15 mm from the casting OD. In order to test this theory, a section was made through a rough casting (unmachined) at the bottom. It is shown in Figure 7. The grain structure revealed can be seen to be the same columnar structure which was seen in the questionable areas. This lends credibility to the proposed theory.

Conclusion:

The dark patches appearing in the radiograph consist of metal with columnar grains as opposed to equiaxed grains. The columnar grains may be slightly lower in tin content. Metallurgical tests indicate that this metal has mechanical properties favorably comparable to that of the surrounding metal. Therefore the appearance of these dark patches on the radiographs is not cause to scrap the bearings.

W. J. Whitney

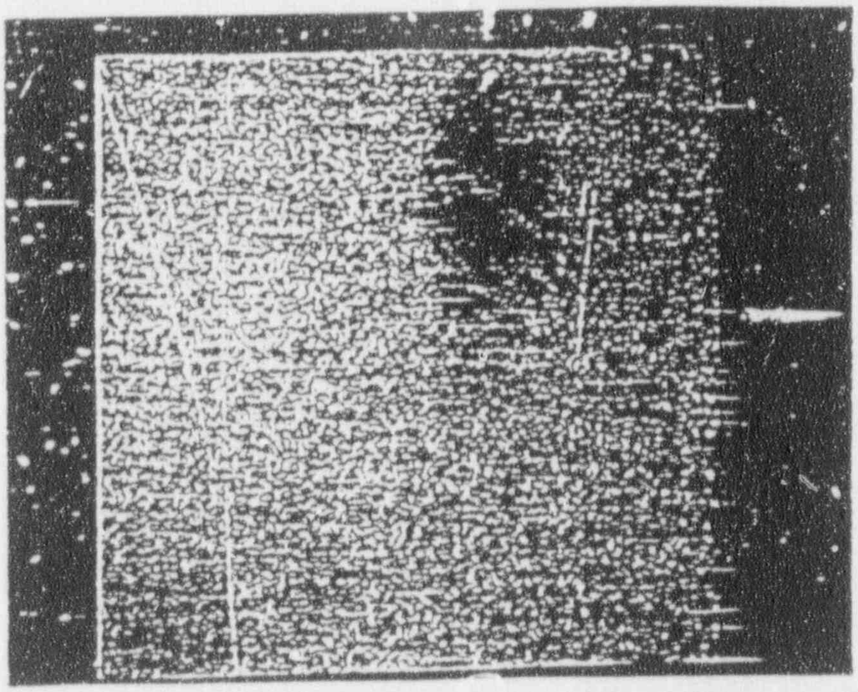


Figure 1. Macro Etched Sample A. 6X. Heavy Keller's Etch.
ID is to the right.

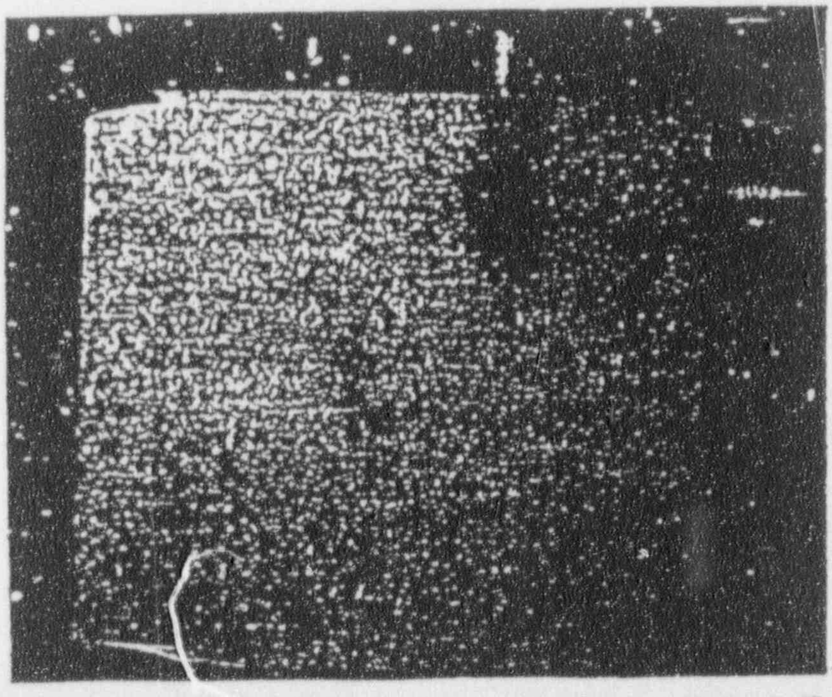


Figure 2. Macro Etched Sample B. 6X. Heavy Keller's Etch.

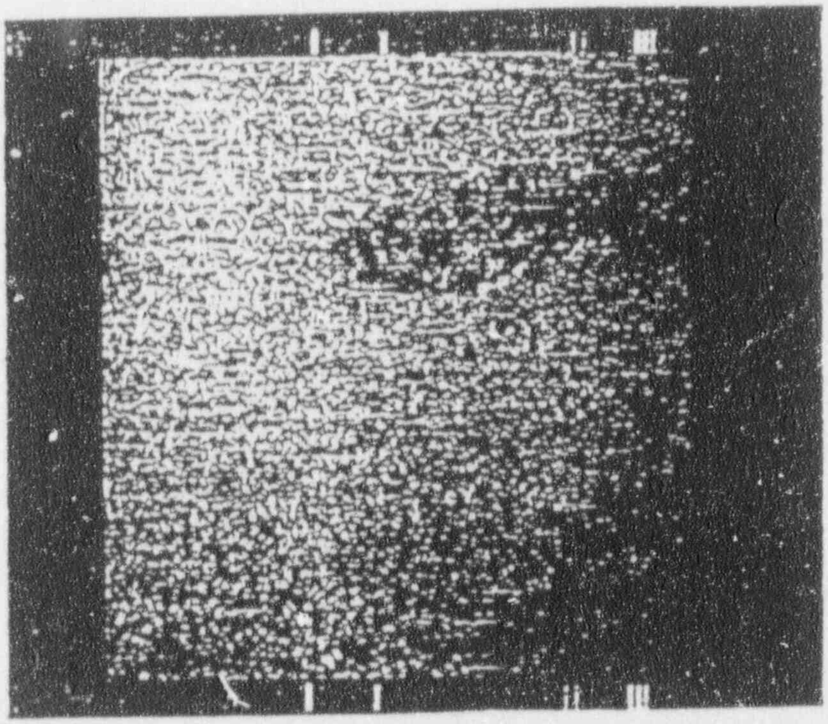


Figure 3. Macro Etched Sample C. 6X. Heavy Keller's Etch. ID is to the top.

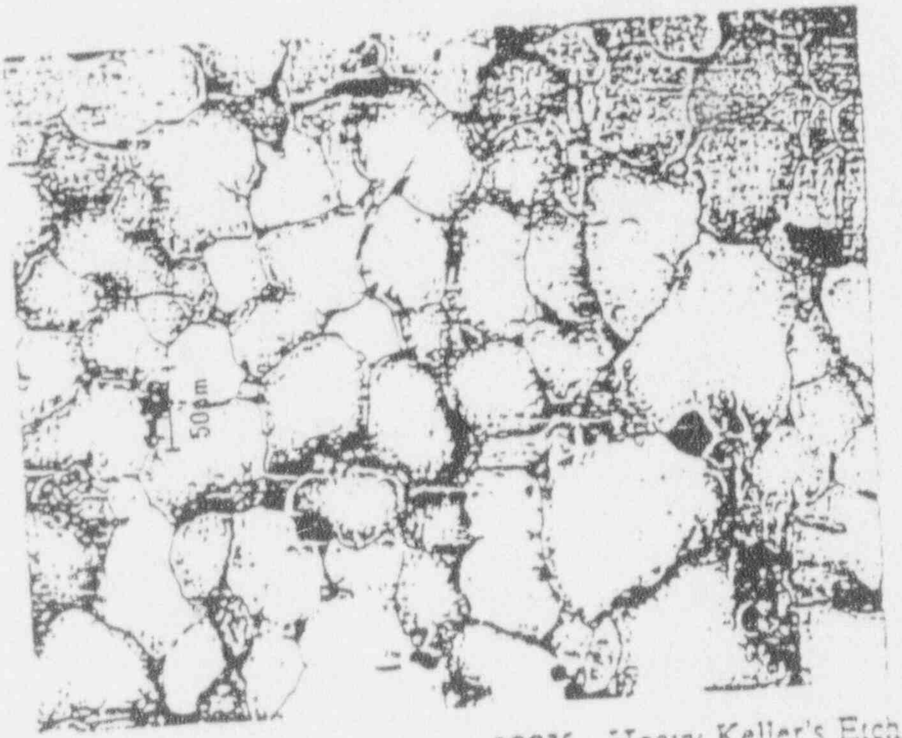


Figure 4. Equiaxed grain area. 200X. Heavy Keller's Etch.

Figure 5. Columnar grain structure. 200X. Heavy Keller's Etch.

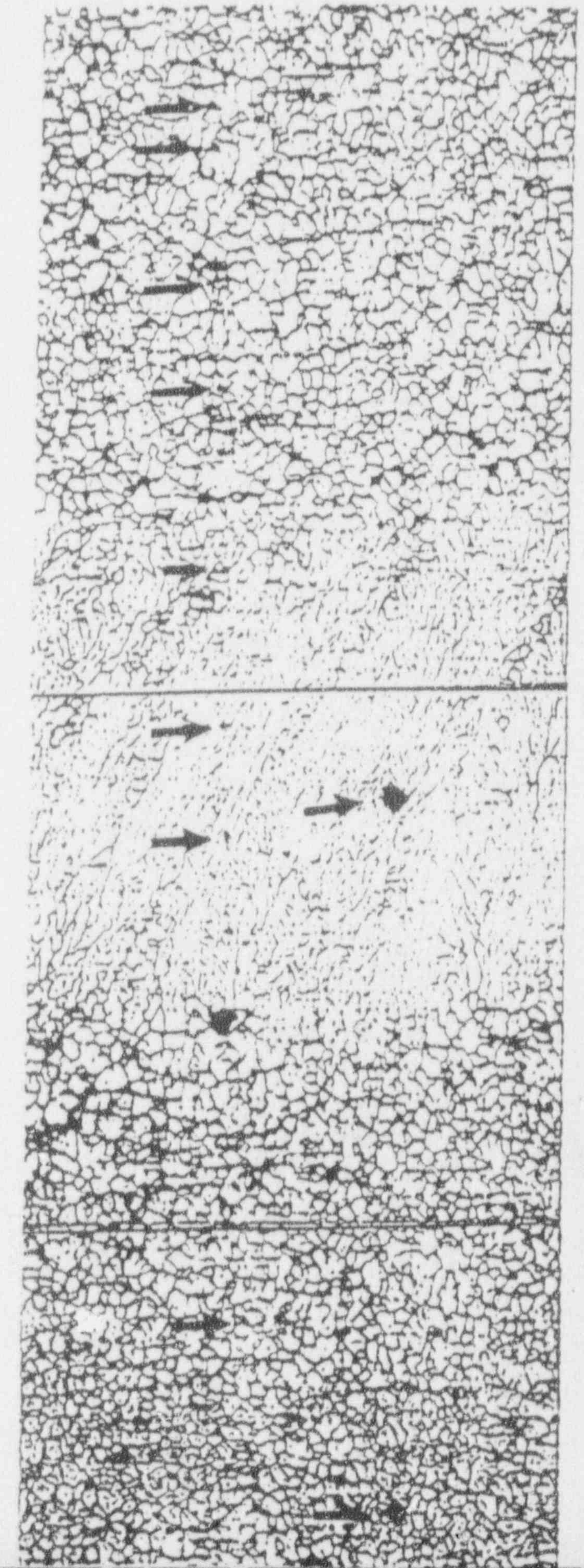


Figure 6. Panoramic view through the columnar area Showing the hardness test indentations. 38X. Heavy Keller's Etch.

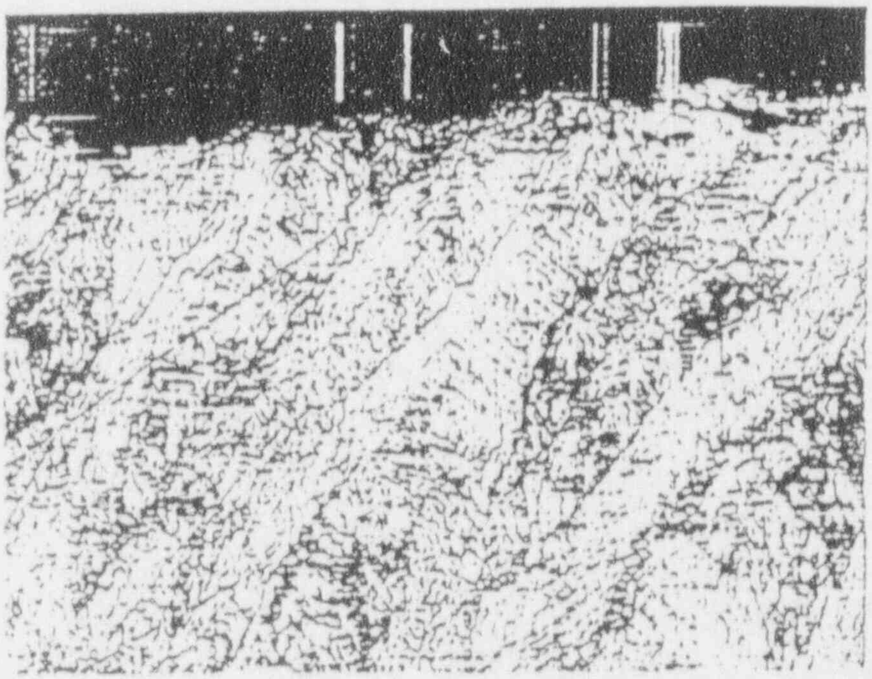


Figure 7. Cross section through surface of unmachined casting. Note similarity to center area of Figure 6. 50X. Heavy Keller's Etch.

REALTIME X-RAY REVEALS BONUS INFORMATION

James L. Wheelis,
Magnaflux Corporation

Presented August 16, 1989 at

the Air Transportation Association
Nondestructive Testing Forum

Special acknowledgement for technical support from:

James Donaldson
Gerald Mason
Michael Moore
Eric Strauss
Ward Rummel

Abstract:

A radiographic phenomenon, termed "Ghost indications", which appear to be but are not necessarily rejectable defects, is described. The ambiguous nature of these indications can result in a sound structure being rejected, or unsound structure being placed in critical service.

The mechanism of the occurrence and a means to differentiate between "ghost" and true indications is explained.

History:

The "ghost" or x-ray diffraction phenomenon has plagued the radiographic inspection business since crystalline structures were first radiographed.

General knowledge of the existance of this phenomenon coupled with extensive destructive verification, has allowed some very experienced radiographers to make judgment calls in noncritical areas. An excellent paper was presented in Material Evaluations, Dec., 1965, Rummel & Gregory " 'Ghost Lack of Fusion' in Aluminum Alloy Butt Fusion Welds", differentiating "ghost" indications from true defects in a specific inspection application.

The increased use of exotic (especially copper bearing aluminum and high nickle) alloys increases the number and severity of diffracted indications. Directionally solidified and single crystal structures are nearly impossible to radiographically inspect without very costly and time consuming techniques. Today, due to these limitations and the extremely critical nature of the air transportation industry, radiographers are justifiably reluctant to make judgment calls. A method which would assist the radiographer in confidently differentiating "ghost" from rejectable indications, could lower scrap rates while assuring that truly rejectable parts do not reach critical service.

Observed Phenomenon:

The operator of the Realtime Microfocus X-Ray Burner Can Inspection System at Northwest Airlines shared his recent experiences with "ghosts" in the image. Indications relating to low x-ray density appear throughout the image, ranging from hazy splotches to sharply defined indications.

NOTE: While indications are quite evident on Realtime monitor, fidelity negates reproduction

This unusual phenomenon was nearly always accompanied by:

1. A mottled background to the image.

2. A dull thud in the traditional tap or "ring" test. i.e., an audible Acustic Emmission indicator.

3. Poor ability to hold a sound weld repair..

A window was cut from a part displaying this ghosting and was replaced with a piece of new material so that a direct comparison could be made.

Upon re-inspection of the windowed part, it was observed that the new material displayed neither the mottled background nor the "ghost" indications. Further investigation revealed that the ghost images did not move in coordination with part motion. When viewed dynamically, the indications moved opposite to the part motion; i.e., if the part was moved from the left to right, the indications would move from the right to left; if the part was moved up, the indication moved down. This "antimotion" made it obvious that the indications were diffracted x-ray patterns rather than defect indications.

To fully understand these observations, a study of the material and the mechanism of x-ray diffraction was undertaken.

Material Study:

A section of the part containing both original and new material was removed for analysis. The chemical analysis showed little deviation from the Hastalloy X® analysis supplied by the alloy vendor, Cabot. It was noted that the sulfur content of the surface analysis was a factor of 10 times higher on the old material than either the vendor analysis or the new material analysis.

After discussion with Northwest personnel a consensus opinion was reached that the increase in sulfur content could be related to the stripping process used to remove the heat resistive coating during rework. The main component of the stripping bath is sulfuric acid, excessive retention of stripping solution or poor neutralization may account for increased sulfur content.

On closer observation the surface of the old material shows an extremely rough appearance. (Photo 1) The open and saw-tooth appearance of the cracking also indicated a large grain presence. These observations were supported with a 500x view of the same surface (Photo 2). This view shows very large grains and severe etching at the grain boundaries. Some grains appear as if they could be lifted from the surface. When compared to the new material at 1000x (Photo 3), the evidence supporting the high sulfur content theory is conclusive. The extremely large grains also indicate that this part was not properly annealed.

The open boundaries would account for the mottled image, the dull 'thud' in the tap or ring test, as well as the inability to hold a good weld repair. The ghosts in the image are a result of the x-ray beam being diffracted from the indices of the large grain structure. In this case the appearance of any "ghosting" is an indication of poor or no annealing and is cause for rejection on its own. This information in itself is an unexpected bonus for the realtime inspection. Yet, the study of the x-ray diffraction phenomenon also revealed more universally useable information.

X-Ray Diffraction

The Rummel/Gregory paper was used as base point to study the diffraction mechanism.

Excerpt:[1]

> X-ray Interaction
> When a beam of X-rays strike a crystal, part of the beam is transmitted, part of the beam is scattered. One of the mechanisms for X-ray scattering is by diffraction from the same manner as a grating diffracts ordinary light. Now, if a series of crystals (crystallite planes) are properly oriented with respect to an X-ray beam, a "focusing" effect will be observed on the radiograph, in the form of a dark band (see Figure 6).....
> NOTE : Relabeled Figure 1

Taking this classically correct explanation and graphic display and applying it to the observed phenomenon left one of two conclusions. Either the original observations were not diffraction related or a much more complex mechanism is occurring.

Close comparison of Fig 1 and the recent observed conditions revealed several differences.

---

1 "Ghost lack of Fusion: in Aluminum Alloy Butt Fusion Welds Ward Rummel and B.E. Gregory Material Evaluations Dec 1965

1. With film radiography, the source-to-object distance was sufficiently long to assume near parallel incident rays. With Microfocus Realtime X-ray, the source-to-object distance was under 5 inches and the divergance of the x-ray beam must be considered

2. With film radiography the object-to-film distance is always kept to a minimum, preferably zero. With Realtime Microfocus, the image plane-to-object distance was 15 inches or a 3:1 projection ratio. The travel length of the diffracted ray must now be considered.

3. Weld inspection has a linear area of interest. In this case the diffraction phenomenon could consider only those indications appearing parallel to the weld. Burner can inspection is concerned with any indication in any axis and the diffraction planes are completely random with no preferential alignment.

Grappling with these differences, at length with scratch pad and pencil, lead to the understanding that the mechanism had not changed from the classic presentation (Fig 1), but had multiplied its variables such that it was very difficult to conceive a graphic representation to depict such variables.

An Autocad Graphics Computer and a talented operator made short work of this task, one that had eaten many frustrating hours of free hand sketches. Only when all the variables were laid out and manipulated was a true understanding of the geometric related information conceived. An understanding of this phenomenon leads to the ability to test conculsively whether any indication in any material is caused by x-ray diffraction.

Geometry of X-ray Diffraction

Figure 2 is a graphic representation of observed realtime geometry. Here, beam divergence and source-to-object-to-image plane relationships are taken into consideration.

To clearly understand the antimotion phenomenon, we must consider an individual ray trace. From Theory of X-ray Diffraction in Crystals (W.H. Zachariasen, Dover Publishers, published 1967), we accept the given that the diffracted beam will exit the indices at an equal and opposite angle to the entrance of the incident or primary ray. Using this given, we can now look at one event (Figure 3), in the A position, then moving only the diffracting indices to the B position. The resulting opposite shift of the diffracted beam now supports the "anti-motion" in the observed realtime x-ray image.

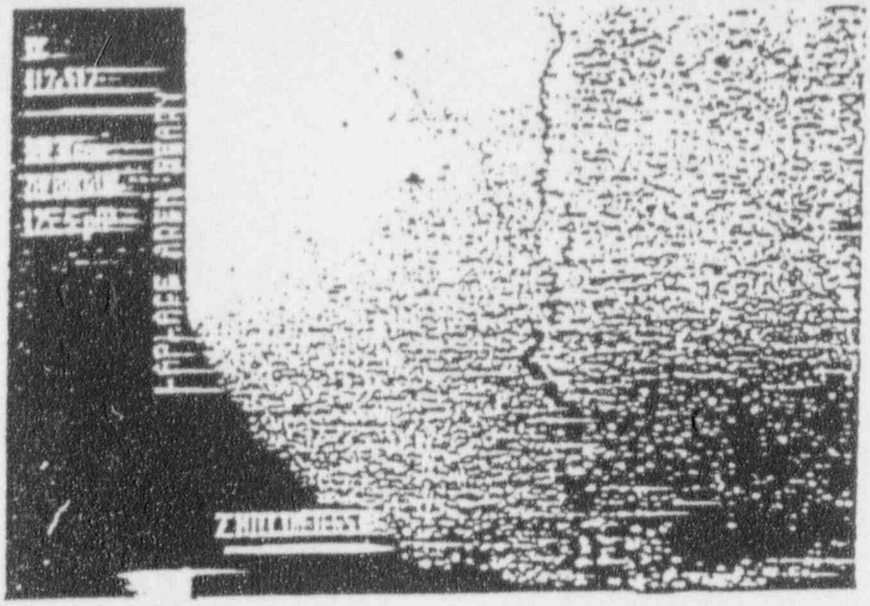
Even more interesting, is the effect of varying the object-to-image plane distance. If the ratio of source to object vs object to image plane is 1:0, equal motion occurs. If the ratio is 1:1, no motion is apparent in the diffracted indication when the object is moved. At 1:2 ratio, equal but opposite motion occurs.

Displaying this in three dimensions (Figure 4) thus accounting for the cone of divergent radiation and the vertical and diagonal effects can be comprehended.

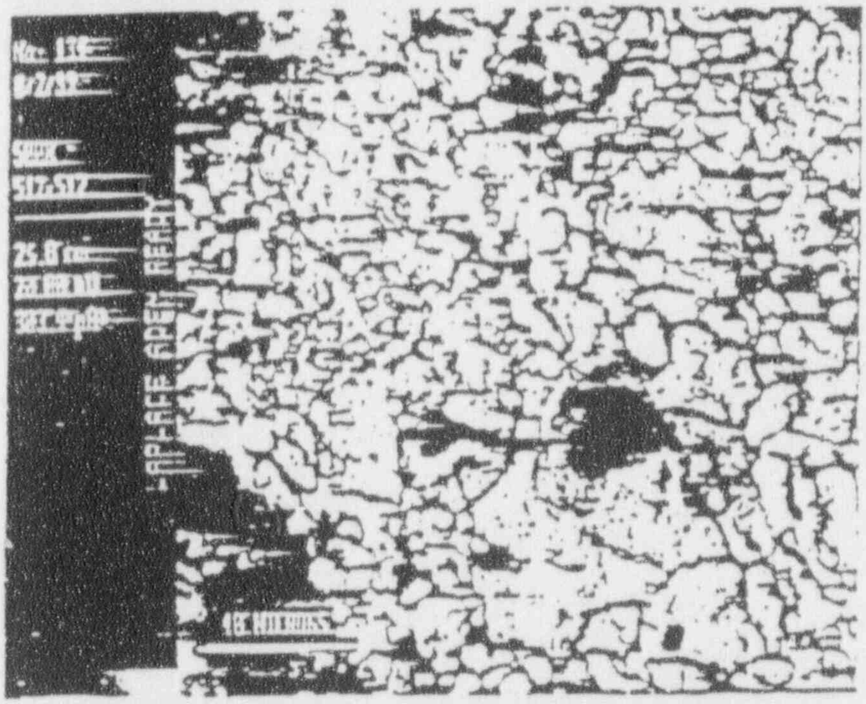
Conclusion:

Using the geometric effects as explained here in the operation of realtime x-ray imaging equipment can conclusively identify diffraction phenomenon. By varying the position under known source-to-object-to-image plane geometries diffracted indications will vary in a predictable manner.

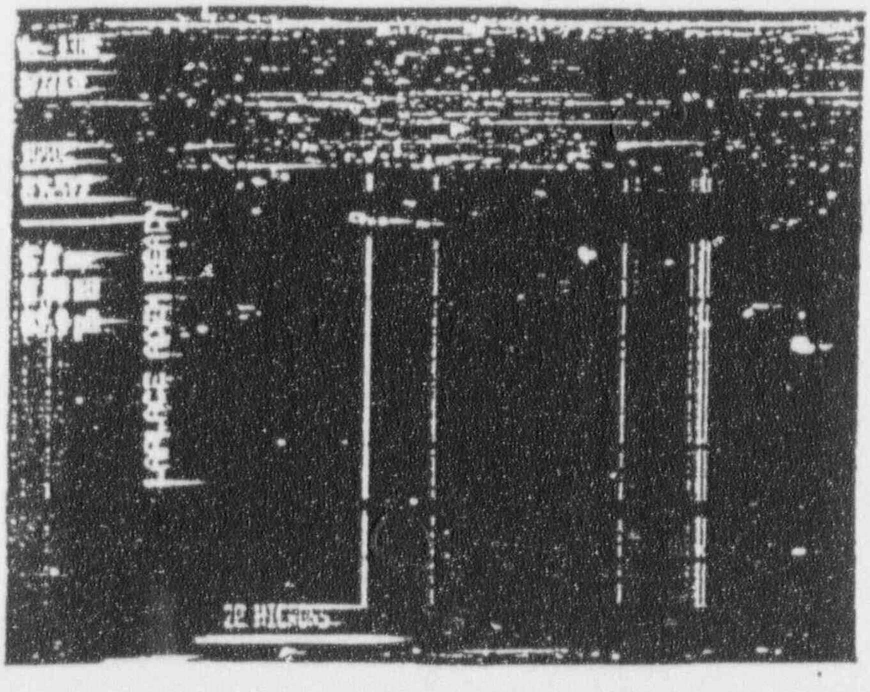
When using an x-ray source of sufficiently small focal spot to allow some variation in object-to-film distance, a film radiograph could be reshot to confirm the origin of suspicious indications.



(Photo 1)

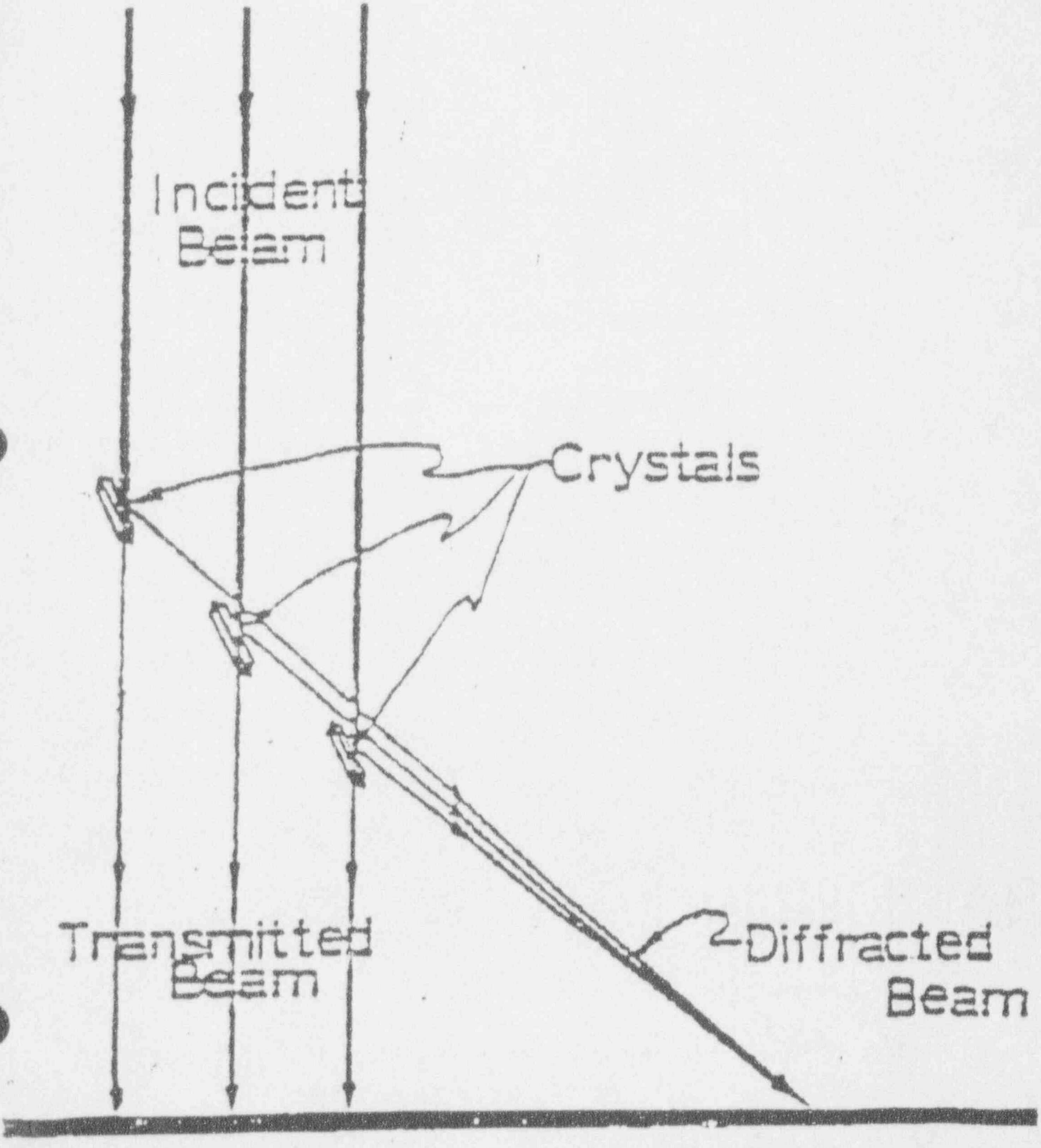


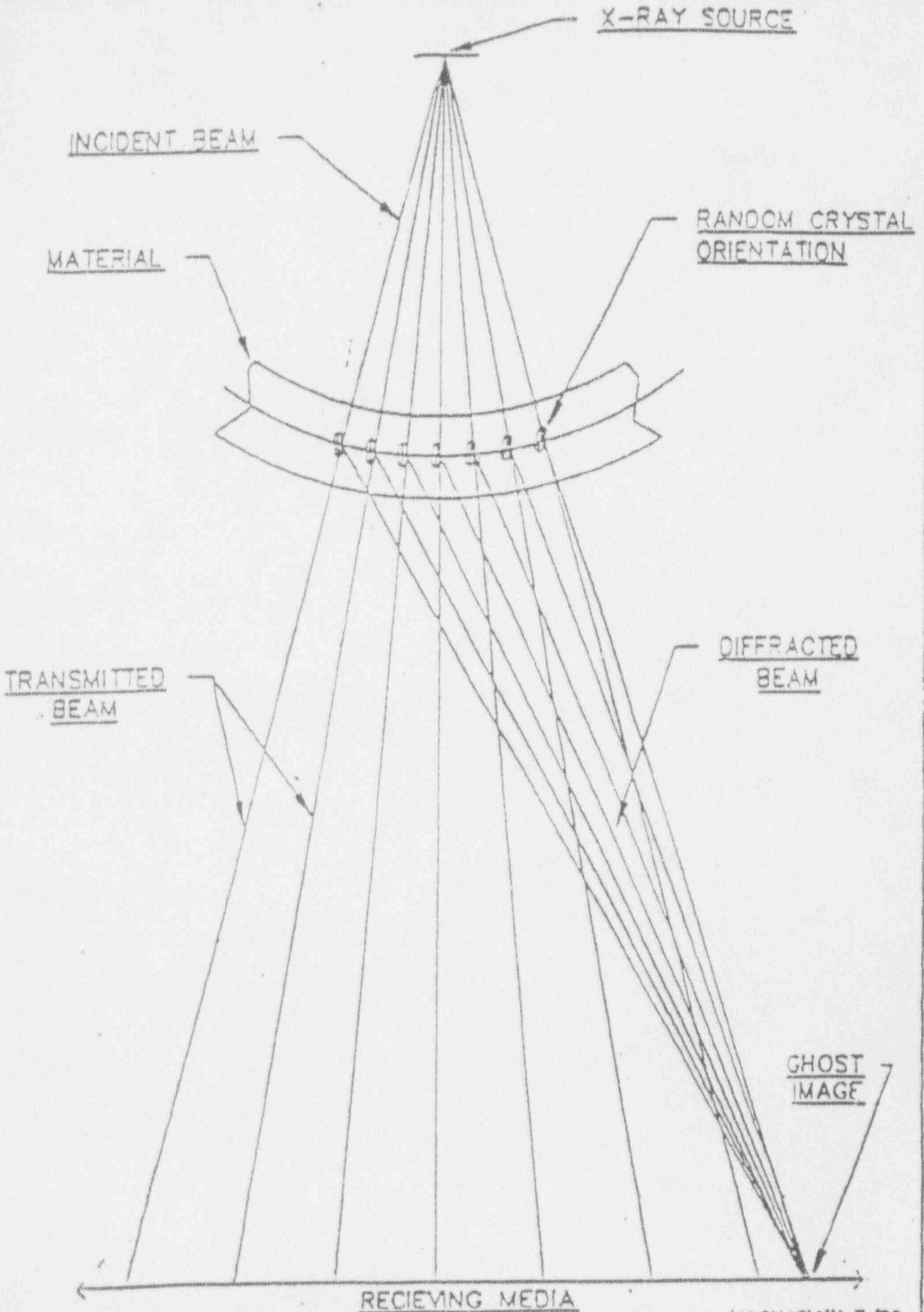
(Photo 2)



(Photo 3)

FIG. 1





MAGNAFLUX 7/89

FIGURE 2

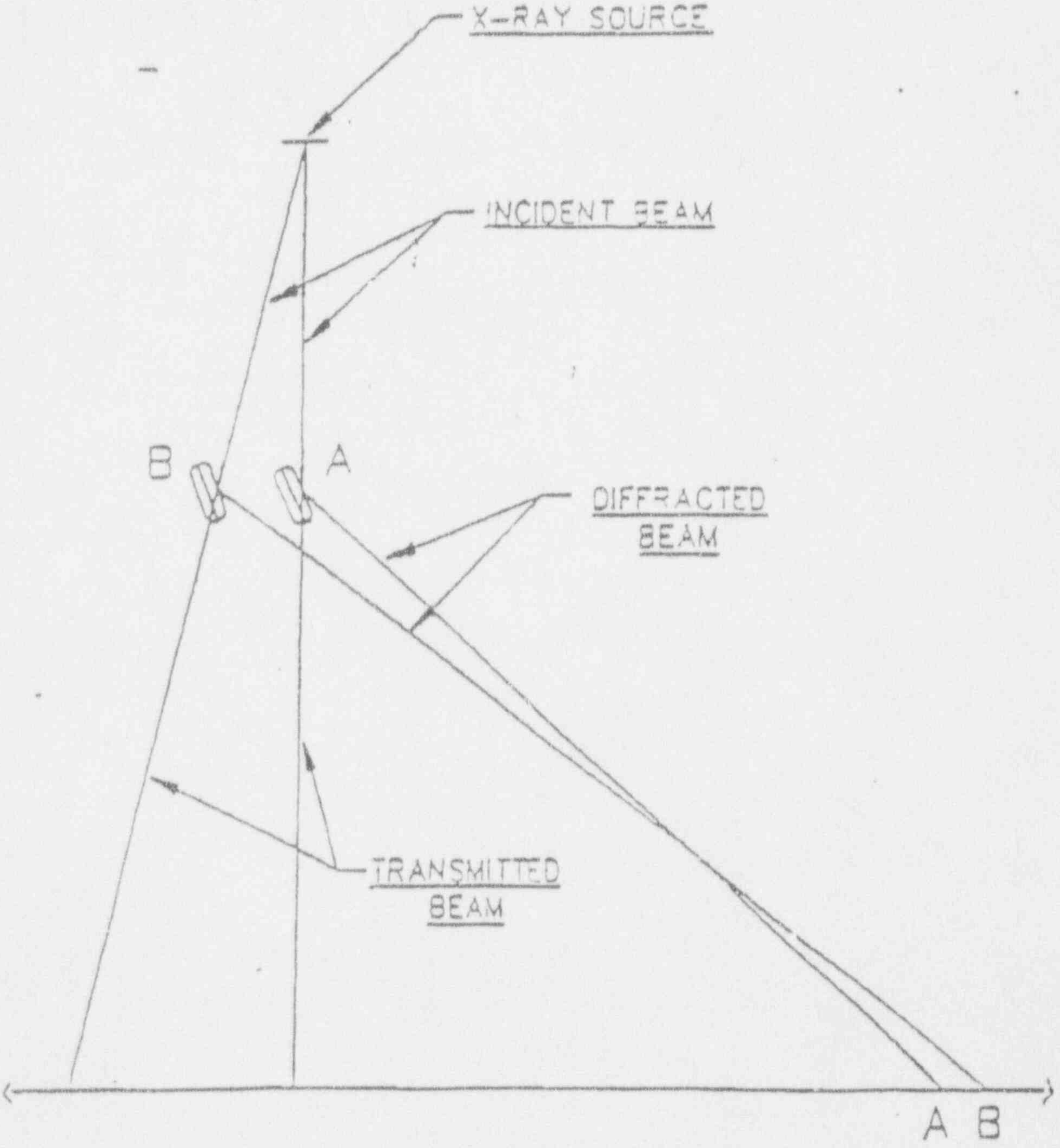


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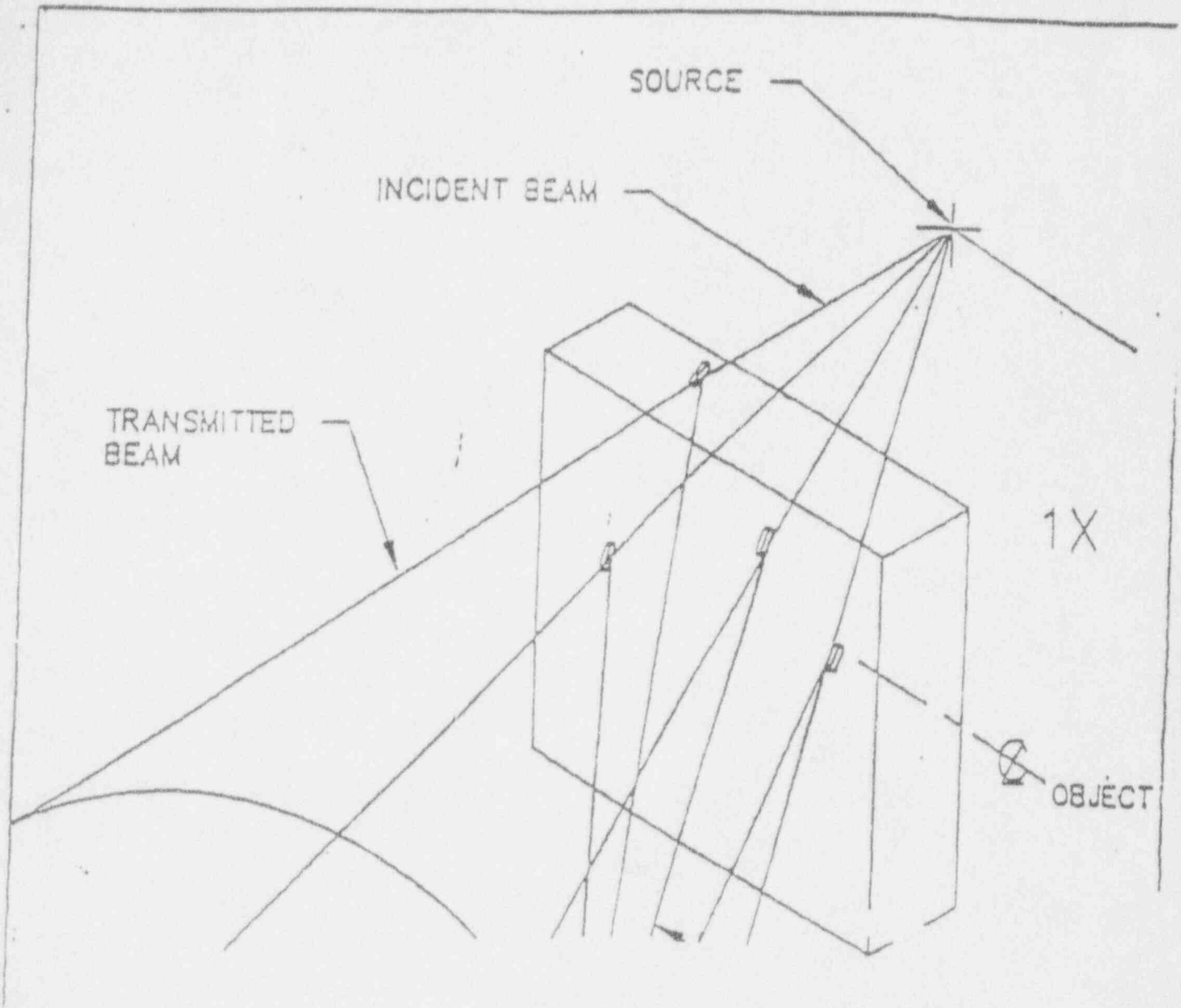
FIGURE 3


SOURCE
INCIDENT BEAM
TRANSMITTED BEAM
1X
OBJECT

ATTACHMENT 2

CPSES 9117826
SU 910310
July 15, 1991

TO: J.B. George

SUBJECT: Radiography Requirement for Enterprise Bearings

REFERENCE: DR/QR RReport 02-340 B

Referenced report, prepared by a consultant to the owner's group, suggests that TDI bearings will be acceptable provided they pass a radiographic examination performed by that consultant. This study was initiated as part of the owner's group effort to qualify TDI diesels and included such events as discovery of cracked connecting rod bearings at Shoreham in 1983, and reports from TDI Vee Engine owners of cracked bearings. Portions of this report have not been endorsed by Enterprise as discussed below.

Bearing shell cracking has never been a problem in the in-line engines such as used at Shoreham. It has always been our contention that the cracking noted there was caused by use of connecting rods with an extremely large bore end chamfer, which allowed the bearing ends to be unsupported, combined with significant engine overloading. The con-rod condition was corrected immediately. No more cracking occurred.

Vee engines in those days utilized connecting rods assembled with what we now know was insufficient fastener preload, causing excessive flexure, or micro-distortion of the big end of the rod. This condition caused the highly publicized con-rod rack tooth fretting phenomena. Of greater importance however, was the effect of this flexure on the rod bearing, especially if that particular bearing was brittle, i.e. of extremely low ductility. Most of the failure analysis studies done at Enterprise on bearings which cracked for no immediatley apparent reason reported bearing shell elongation numbers either nil or less than 1%. Some had regions of casting porosity on or near the crack surface, but most did not.

TDI supplied bearings made and plated in their factory from Aluminum/Tin castings made at Alcoa in Cleveland. These castings were statically cast in a permanent mold and, from time-to-time exhibited less than adequate mechanical properties. Porosity was also sometimes a problem, and resulted in inability to satisfactorily electroplate the lining on the piece, easily detectable in the plate shop. Note also that pores as small as .010"/.020" were easily visible. In no case would pores of .050" allow plating to be acceptable.

In the early 1980's the fastener preload on Vee Engine con-rods was significantly increased. Rack tooth fretting, while still not zero has been reduced from very significant to almost nil. In the mid 1980's, destructive testing of each heat of bearing castings was begun to verify adequate mechanical properties.

Operating experience after these changes was most satisfactory, bearing shells routinely lasting 20,000/25,000 hours (BY NO MEANS 38,000 HOURS). Shells are replaced based on wear limits rather than base metal condition, in conjunction with general overhaul activities near this hour level. None of these bearings were radiographed.

In 1988, Enterprise ceased manufacture of bearings, opting to purchase these parts in finished form from Federal Mogul, a worldwide supplier of all kinds of engine and compressor bearings, including bearings for engines which could have been installed in nuclear generating stations. F-M is not aware of any radiograph requirement for these parts.

F-M uses the centrifugal casting method to obtain consistantly high quality castings. This method affords the foundryman various options such as mold spinspeed, pour rate and cooling rate to further enhance casting quality. F-M asserts this fine tuning is normal and on-going, and may be the cause of radiograph ghost imaging, as the report I gave you suggests. F-M furthermore applies a flash of plating to the back of the bearing, the lead/tin content aggravating X-Ray problems, but improving its grip in the housing. F-M bearings have been in use in Enterprise Vee Engines for thousands of hours. No reports of bearing quality problems have been received. None of these bearings were radiographed.

In summary, I submit that the onerous radiographic suggestion of referenced report was of questionable value in the beginning, and certainly is of no value now. Not only have the con-rod problems finally been solved with the use of adequate fastener preload applied by hydraulic tensioning tools, but also the bearings are manufactured by avendor specializing in this work, utilizing a completely different methodology than the TDI/Alcoa method employed.

M. H Lowrey

M. H. Lowrey
Cooper Industries

Distribution:

M. L. Bagale
Ken Dixon
Bo Weir

APPENDIX D

APPENDIX D

DUKE ENGINEERING
& SERVICES, INC.

230 South Tryon St.
PO Box 1004
Charlotte, NC 28201-1004

Bus (704) 373-2473
Fax (704) 373-2696

February 27, 1992

Mr. P. Om Chopra
Office of Nuclear Reactor Regulation
Electrical Systems Branch (MS 7 E4)
U. S. Nuclear Regulatory Commission
Washington, DC 20555

Re: Cooper-Enterprise Clearinghouse Group
Diesel Generators
Position Paper on Radiograph Requirements
for Connecting Rod Bearing Shells
File: MTS-4086

Dear Mr. Chopra:

Enclosed is additional information to clarify questions in regards to certain proposed process changes related to radiography of the connecting rod bearings. This information supplements our previous letter dated October 31, 1991.

The Cooper-Enterprise Clearinghouse Group requests you review the enclosed document and based upon the complete technical justification provided, evaluate and concur with the Clearinghouse that current radiographic requirements are not necessary for Cooper Enterprise EDGs.

Response to this issue by March 20, 1992 will be greatly appreciated by the Clearinghouse and the individual utilities members. Should you have questions, please direct them to Rick Deese at (704) 875-4065.

Very truly yours,

V. M. Anthony
for R. D. Broome
Project Manager
Cooper-Enterprise Clearinghouse
Duke Engineering & Services, Inc.

J. B. George
Chairperson
Cooper-Enterprise Clearinghouse
TU Electric

RDB/VMA/021492

Enclosure

cc: E. B. Tomlinson (NRC)
Clearinghouse Representatives
R. J. Deese

Federal-Mogul Corporation
451 County Line Road
Mooresville, Indiana 46158
Tel. 317-831-3830
Fax 317-831-7035

FEDERAL
MOGUL

January 24, 1992

Jules Hudson
Cooper Energy Services
14490 Catalina St.
San Leandro, CA. 94577

Mr. Hudson:

In response to your fax dated January 10, 1992; there are many processing techniques to reduce or eliminate the existence of gas entrapment within the bearing.

Here at the Mooresville facility, we use the centrifugal casting process. This process inherently lends itself to the elimination of gas bubbles, drosses, and oxides due to the outward radial force (approximately 30-60G) acting on these particles. Since the densities of the aforementioned particles are considerably less than any element in the AA 852.0 alloy, they are forced to the inside diameter of the casting were they are removed by subsequent machining.

To further insure the removal of gasses, hexachloroethane tablets are dispersed into the melt. The tablets decompose to evolve chlorine gas which, in turn, ties up the hydrogen (the primary cause of entrained gas in aluminum) and removes it from the melt. Past foundry testing using reduced pressure tests confirm the expulsion of hydrogen gas via this method.

In addition to production techniques, the process is closely monitored to verify the continued success of these techniques. These include: Individual Process Set-Up Sheets for every job, First Piece Inspection of casting, Fluorescent Penetrant Testing of each heat, and Verification of Mechanical Properties of each heat.

Process Set-Up Sheets:

For every job cast, a Process Set-Up Sheet (see attached) is generated and released to the foundry prior to production. The Process Set-Up Sheet contains all of the vital process parameters needed to produce a particular casting. In addition, it provides documentation of any changes to an existing parameter.

First Piece Inspection of Casting:

Standard practice dictates that first piece inspection be performed on the first casting poured on a job. After cast, the casting is allowed to cool to approximately 300-400 F. The casting is then fractured to reveal four (4) distinct cross sections. These cross sections are evaluated under 10x magnification and inspected for dross inclusions, layering, gas voids, and excessive shrink cavities. This evaluation is documented on the Process Set-Up Sheet.

Fluorescent Penetrant Testing:

The Requirement for fluorescent penetrant inspection (Zyglo) is indicated of the Process Set-Up Sheet. The majority of large castings (>10 - 11 in. dia.) are tested in this manner. A sample casting is poured prior to production and bored to the blue print dimension. The bore surface is evaluated for surface discontinuities which may or may not have been apparent during analysis of the fractured casting.

Mechanical Properties:

At present, a representative casting (termed "lab sample") is poured for each individual heat. This casting provides for both chemical and mechanical testing. Test bars are cut from the lab sample and tested for tensile and elongation properties. This testing provides confirmation that no detrimental defects exist within the test casting.

Under current evaluation is the potential for using separately cast test specimens (.505" standard ASTM tensile bars) to predict the acceptability of production castings. Since the separately cast bars are not under the influence of head pressures greater than 1 x gravity, they will be affected by discontinuities to a greater degree. Therefore, acceptable results obtained via separately cast specimens would insure a degree of confidence in the centrifugally cast product.

I hope that this information assists you in your communication with the NRC. If you need any additional information, please feel free to contact me.

Sincerely,

Brett L. Bridgham
Plant Metallurgist

Copy: D. Jackson
R. Moore
D. Pazuk
Mooresville Lab File

ustomer: CES
art No.: R-3313

Die (Conv) : PEL-8 Die (CNC) :
Cast Wt(1) : 180# Cast Wt(2):

lloy : B850
ertification ; Chemistry : Y
; Mechanical: Y

Specification: CES D4998
ip (y/n) : Y
ner :

***************** INITIAL SETUP *****************

etal Temp : 1350
ie Temp : 300
RPM : 400
lux : 2#11
ast Start : 2 SEC

ast I.D. : 10"
ast Weight: 180#
.D. Stock : 1.328
.D. Stock : .589
AL. Stock : 4.201

Spray Tower "A"
Nozzle Type (a): 50/10
Locations (a): 1,3,5

Spray Tower "B":
Nozzle Type (b): 50/10
Locations (b): 2,4,6

Water Delay : 15 SEC
Cool Time : 4 MIN
Water Temp :

******************** PRODUCTION HISTORY ********************

OB NO. :
.E. NO. : 91-3033
ATE :

CAST QTY. : 7/14
PCS/HR :

etal Temp ______
ie Temp ______
RPM ______
lux ______
ast Start ______

ast I.D. ______
ast Weight ______

Spray Tower "A"
Nozzle Type ______
Locations ______
Spray Tower "B"
Nozzle Type ______
Locations ______

Water Delay ______
Cool Time ______
Water Temp ______

Change	Reason	Result

******************** WEIGHT REPORTING ********************

Date	Shift	Scrap Lbs	Good Lbs	Fract Cast	Other Scrap	Good Cast	Bal Req

APPENDIX E

[illegible] DCN

7.6.1 Attach G.2 ~~GAY~~

Received from Go

cc: B Camic
R Walker
Terry
J Kelley
~~WRM~~ M Blevins
for your info
1/5/93

Dierk Reimer

FYI

Received
JAN 5 - 1993
SCG

UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555

DEC 01 1992

Mr. J. B. George, Chairperson
Cooper Enterprise Clearinghouse
C/O Duke Engineering
230 South Trion Street
Charlotte, NC 28201-1004

Dear Mr. George:

Reference: Letter from R. D. Broome to O. Chopra, dated October 31, 1991

In the above referenced letter you requested relief from the current radiographic examination requirement used to detect voids and impurities previously found in cast aluminum connecting rod bearing shells used in your TDI diesel engine. This requirement was originally proposed by the TDI Owners Group and accepted by the NRC staff for purposes of inspection of TDI diesel engine connecting rod bearing shells manufactured by ALCOA. This requirement was detailed in Appendix II of the Design Review/Quality Revalidation Report for TDI diesel engines.

We have reviewed the technical justification to delete the radiography requirement in your position paper attached to the above referenced letter. We note that the replacement bearings originally supplied by ALCOA are presently manufactured by Federal- Mogul Corporation. Federal Mogul fabricates its bearings by centrifugal casting, an alternative to Alcoa's static casting process. Unlike static casting, centrifugal casting significantly reduces the potential for void formation. Furthermore, the manufacturer has demonstrated that, through choice of manufacturing processes and quality assurance measures, the cast aluminum engine bearings will have an acceptable level of quality and safety. These alternative approaches and inspections should be as effective as the previous requirement of radiographic inspection of static cast bearings to detect voids and the presence of impurities. On this basis, the requested relief from requirements to inspect diesel generator connecting rod bearing shells by radiographic techniques for DSR-8, DSRV-16, and DSRV-20 engines is granted. A copy of our safety evaluation is enclosed.

Sincerely,

For

James E. Richardson, Director
Division of Engineering
Office of Nuclear Reactor Regulation

Enclosure:
As stated

UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D. C. 20555

ENCLOSURE

SAFETY EVALUATION

POSITION PAPER FOR NOT PERFORMING RADIOGRAPHIC EXAMINATION OF REPLACEMENT DIESEL GENERATOR CONNECTING ROD BEARING SHELLS FOR ENTERPRISE DSR-8, DSRV-16 AND DSRV-20 DIESEL ENGINES

1.0 INTRODUCTION

By letter dated October 31, 1991, Cooper Enterprise Owners Group requested relief from the current radiographic examination of connecting rod bearing shells for Enterprise DSR-8, DSRV-16, and DSRV-20 engines (originally TDI diesel engines). This requirement was originally proposed by the TDI Owners Group and imposed by the staff for replacement connecting rod bearing shells manufactured by ALCOA as detailed in Appendix II of the Design Review/Quality Revalidation Report for TDI diesel engines. Our evaluation of the technical justification provided by the Cooper Enterprise Clearing House Group is as follows.

2. EVALUATION

The subject position paper proposes to eliminate the need for radiographic examination of the currently supplied centrifugally-cast aluminum bearing shells from Federal Mogul. When the radiographic requirements were established, the aluminum bearing shells were made from aluminum casting supplied by ALCOA that were manufactured by a permanent mold static casting process. Past failures of the bearing shells were attributed to 1) inadequate clamping force in the connecting rod assembly due to inadequate pre-load of the connecting rod bolts, 2) inadequate support at a bearing end because of a 1/4 inch chamfer, and 3) potential voids and/or impurities induced into the bearing shell during the casting process. The problems were corrected by 1) increasing connecting rod bolt pre-load, 2) reducing the size of the chamfer to 1/16", and 3) inspection by radiography of the bearing shells to detect voids or impurities.

The position paper and its supporting documentation addresses the problem of the unnecessary rejection of bearings for radiographic indications. The indications are fuzzy dark areas on the film; these can indicate porosity or inclusions, causes for rejection. Tests, however, showed that the dark spots may correspond to areas of columnar grains and minor differences in chemical composition. Evidence shows the spots are likely caused by diffraction of the X-ray by this grain structure.

Although the paper showed that these indications can lead to rejecting sound castings, it did not describe how to differentiate columnar grain structures from rejectable defects or other ways to assure the quality of the bearings. Federal Mogul provided this information in a letter dated January 24, 1992. This information demonstrated that there were production procedures and quality control tests which provide adequate assurance that these castings will be produced without defects of significance. The combination of centrifugal casting versus static casting, the removal of hydrogen by chemical means, destructive first piece inspection, fluorescent penetrant testing of a machined part prior to production, and the static casting of mechanical test specimens for centrifugal cast products provide an acceptable level of quality which should assure that voids and impurities will be detected in test specimens prior to their being generated into a finished production part.

Based on a review of the information provided by the Cooper-Enterprise Owners Group as discussed above, the staff concludes that the manufacturer has demonstated that through choice of manufacturing processes and quality assurance measures, the centrifugally-cast aluminum diesel engine bearings will provide an acceptable level of quality and safety. These alternative approaches and inspections should be as effective as the previously required radiographic inspection of static cast bearings to detect voids and impurities. Therefore, the requested relief from the current radiographic examination of centrifugally-cast aluminum bearing shells manufactured by Federal-Mogul for Enterprise DSR-8, DSRV-16, and DSRV-20 diesel engines is granted.

DE&S
Duke Engineering & Services

230 South Tryon Street
P.O. Box 1004
Charlotte, NC 28201-1004

(704) 382-9800 Bus
(704) 382-8389 Fax

December 7, 1993

Cooper-Enterprise Clearinghouse Representatives

Subject: TDI Owners Group
Information Bulletin DCH9365
MTS-2242

Gentlemen:

Enclosed is the referenced TDI Owners Group Information Bulletin. No response is required. If you have any questions, please direct them to me at (704) 382-2763.

Sincerely,

RCDay/rfm

R. C. Day, Project Engineer
Advanced Nuclear Programs

RCD/rfm

Enclosure

xc: Project File
Central Records

COOPER-ENTERPRISE CLEARINGHOUSE

MAILING DISTRIBUTION LIST

TU ELECTRIC
Mr. Joe George ☒
Mr. Manu Patel ☒
Mr. Gary Yezefski ☒

GULF STATES UTILITIES
Mr. Brian Fichtenkort ☒
Mr. T. E. Scheibel ☐
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COOPER-ENTERPRISE
Mr. Bruce Guntrum ☐
Mr. Allen Gillette ☐

DUKE ENGINEERING & SERVICES
Mr. Skip Hendrix* ☒
Mr. Rick Deese* ☒
Mr. Dick Day* ☒

CEMASTER.ppt

*Duke interoffice Mail

Dec. 7, 1993

DCHF2 REV. 1

NO. DCH9365
DATE 12-7-93

DUKE ENGINEERING & SERVICES, INC.
DELAVAL DIESEL GENERATOR CLEARINGHOUSE
INFORMATION BULLETIN

INFORMATION ONLY ☐	**RESPONSE REQUESTED** ☒ **(if checked see below)**

SUBJECT: Meeting with NRC to discuss TDI Emergency Diesel Generator Licensing Submittal - Supplement #2 - December 14, 1993

- Enclosed is a copy of Mr. George's and Mr. Hendrix's letter to Mr. James A Norberg, NRC, dated December 7, 1993.
- Enclosed is a copy of the agenda for the meeting with the NRC.

The meeting will be held on December 14, 1993, at 1:00 pm in the NRC offices in White Flint, MD. Please confirm your attendance, by fax 704-382-8770 or phone 704-382-4390 to Robbie McDonald, no later than **Friday, December 10.**

- Enclosure 3 pages

Submit Response to:

R.C. (Dick) Day
Duke Engineering & Services, Inc.
230 South Tryon Street
P.O. Box 1004
Charlotte, NC 28201-1004
Telecopy No. (704)382-8770

IF YOU HAVE ANY QUESTIONS, PLEASE CONTACT R.C. DAY AT (704)382-2763.

DCHMASTE.wp

DE&S
Duke Engineering & Services

230 South Tryon Street
P.O. Box 1004
Charlotte, NC 28201-1004

(704) 382-9800 Bus
(704) 382-8389 Fax

December 7, 1993

Mr. James A. Norberg, Chief
Mechanical Engineering Branch
Nuclear Regulatory Commission
Washington, DC 20555

Subject: Cooper-Enterprise (TDI) Owners Group
Generic Licensing Submittal No. 2 for Emergency Diesel
Generators Conditions of License for
Utilities with Enterprise Engines

File: MTS-4086

Dear Mr. Norberg:

Please find attached the Cooper-Enterprise (TDI) Owner's Group's Supplement 2 to their December 8, 1992 submittal addressing diesel maintenance requirements contained in each owners license. In accordance with our September 30, 1993 latter Supplement 2 contains the following documents:

1) Discussion of inspection results and conclusions for the thirteen components addressed in the September 30, 1993 letter. (Attachment 1)

2) Sample data table (annotated). (Attachment 2)

3) Data table containing summary of inspection results for thirteen components. (Attachment 3)

4) Summary of Owner's Technical Specification requirements for Cooper-Enterprise Diesel maintenance. (Attachment 4)

The Cooper-Enterprise Owner's believe that the above information fully supports the issuance of a Safety Evaluation Report (SER) which removes all maintenance requirements from plant licenses. In order to support plant outage schedules, it is requested that the SER be issued by January 31, 1994. Further the Owner's would like to schedule a meeting with the appropriate NRC staff personnel on December 14, 1993. This meeting would answer any questions concerning Supplement 2, address plant specific requirements and facilitate the development of the SER.

If there are any questions or comments please contact Mr. J. B. George (817) 897-8113 or Mr. R. C. Day (704) 382-2763.

Sincerely,

J. B. George, Chairperson

Cooper Enterprise (TDI) Owners Group

C. W. Hendrix, Jr.,
Project Manager
Duke Engineering
&Services, Inc.

Attachments

xc: Carl Berlinger, NRC w/o attach
Jai Rajan NRC w/o attach
R. C. Day w/ attach
R. J. Deese MCG w/attach
Project File w/attach
Central Records w/o attach

COOPER-ENTERPRISE OWNERS GROUP
(TDI OWNERS GROUP)

DECEMBER 14, 1993

TIME: 1:00PM

MEETING WITH NRC

WHITE FLINT, MD

"TDI EMERGENCY DIESEL GENERATOR"

LICENSING SUBMITTAL

SUPPLEMENT # 2

AGENDA

1.	INTRODUCTIONS NRC & ATTENDEES	J. RAJAN/J. GEORGE
2.	OVERVIEW - LICENSE SUBMITTAL - SUPPLEMENT #2	J. GEORGE
3.	DISCUSSION/COMMENTS -SUPPLEMENT #2 DATA -	
	A. TDI OWNERS INSPECTION RESULTS	R. DEESE/C. HENDRIX ATTENDEES
	B. SAMPLE DATA TABLE	R. DEESE/C. HENDRIX ATTENDEES
	C. TECH SPEC SUMMARY FOR TDI EDG'S	R. DEESE/C. HENDRIX ATTENDEES
4.	OWNERS SCHEDULE FOR SER ISSUANCE	J. GEORGE/OWNERS
5.	NRC SCHEDULE FOR SER ISSUANCE	J. RAJAN/J. NORBERG
6.	COMMENTS/CONCLUSION	J. GEORGE/J. RAJAN

TDI OWNERS' GROUP

LICENSING SUBMITTAL TO ADDRESS TEN-YEAR OVERHAUL

ATTACHMENT I

TABLE OF CONTENTS

1.0 INTRODUCTION

The purpose of this submittal is to address the overhaul frequency of the Enterprise engines currently in service at the following nuclear stations:

UTILITY	STATION
Texas Utilities	Comanche Peak
Entergy Operations, Inc.	Grand Gulf
Duke Power, Inc	Catawba
Carolina Power and Light, Inc.	Shearon Harris
Georgia Power/Southern Nuclear Operating,Inc	Vogtle
Cleveland Electric Illuminating Co./ Centerior Energy	Perry
Gulf States Utilities	River Bend
Tennessee Valley Authority	Bellefonte

This sample represents a total of 20 engines in nuclear related service. Note that the two engines at Bellefonte have limited operating history and are not included in the inspection data. Several of the engines have accumulated between 2000 - 3000 hours of operation which is significant for this application. The sample therefore contains sufficient operating history and experience on which to base determinations regarding the frequency of overhauls.

The definitions of the terms "teardown" and "overhaul" as used in this proposal are provided below.

An explanation of these terms and philosophy requires understanding basis of the Owner's request to eliminate "teardowns" and "overhauls" as a licensing requirement. In most documents the terms "teardown" and "overhaul" are interchangeable. In the context of this submittal the term "teardown" defines an intrusive engine disassembly and inspection aimed at determining the engine's condition. The primary purpose of a "teardown" not to replace parts since most parts being inspected show little or no wear. The purpose of the teardown is to document the condition of the part. However, as a matter of good maintenance practice, parts are generally replaced regardless of condition after a "teardown" inspection. These "teardowns" can result in reassembly errors, entry of foreign materials or increased wear resulting in a decrease in engine reliability. The term "overhaul" is defined as an engine disassembly aimed primarily at replacement of worn parts.

As noted later in this document, most "teardowns" have shown little or no wear on internal components due to the limited number of operating hours on engines in nuclear service. Based on this the Owners expect that true "overhauls" should not be needed over the life of the plant. It is possible that problems could occur with specific power cylinders which could require inspection or overhaul of a particular cylinder. This action will be determined on a case by case basis and will be performed such that engine reliability and availability are maximized.

It should be noted that this submittal is not requesting elimination of the overhaul. It is believed that an overhaul will be necessary during the life of these engines as they are currently operated. However, due to the limited number of run hours and the availability of periods to perform major teardowns (shutdown risk management has decreased the window of opportunity for diesel inspection during normal refueling outages unless alternate sources of power are established and approved by the NRC) it is obvious that utilities need the flexibility to determine when an overhaul is required and the overhaul methodology.

The following sections provide an analysis of the need for engine overhaul as required by the DR/QR. This analysis and conclusions are based on an understanding of the historical concerns for each component affected by the overhaul and the results of extensive inspections performed by the utilities listed above. This information presented includes, component description, component identification number per the DRQR Appendix II, PM Task Description , the manufacturer's replacement/overhaul recommendations, the number of engine run hours between inspections or cumulative engine hours, number of engine starts, inspection findings, and the percentage of all components in service covered by the inspections. Engine inspection data is presented in tabular form in Table 1. Figure 1 provides a sample data table and a definition of each table heading.

It should be noted that the data is a conservative rollup of actual work requests, inspections, and results supplied by each utility. Average and totals taken from this data and used in the report are conservatively rounded to simplify the numbers.

In reviewing the vendor estimate of component life expectancy or overhaul frequency for engines in commercial use several points should be considered:

1) The primary difference between nuclear and commercial service are the fast starts and small number of operating hours on nuclear service engines.

2) The commercial engine life for most components is between a factor of ten and one hundred times longer than a nuclear service engine will log in a 40-year life of service.

3) Recent actions of the NRC will allow utilities to slow start the engines ~ 90 percent of the time making nuclear standby service much more like commercial service.

2.0 BACKGROUND

The performance of overhauls on a strictly time dependent basis to track component wear is costly and unnecessary in light of the many non-intrusive engine monitoring techniques available for determining the health of the engine. In fact, industry data and Owner's Group inspection results show that these intrusive inspections show little component degradation and can actually be detrimental to engine reliability and availability. Finally, these overhauls significantly increase engine unavailability during the refueling outage with attendant increases in shutdown risk. Additional detail on each of these issues is provided below.

The performance of a major engine overhaul has been shown to actually decrease engine reliability and availability for a significant period of time following the overhaul. Studies performed for the NRC (Reference: NUREG/CR-5078, PNL-6287, NUREG/CR-4590, NUREG/CR-5057) indicate that for approximately 2 years following a major engine overhaul, EDGs, regardless of their manufacturer, exhibit increased unreliability. There are a number of reasons for this increase. First, during disassembly there is a high potential to introduce dirt and other foreign materials that may damage the engine. Second, disturbing a precision fit system that "wears in" to seat mating surfaces (e.g. rings and liners, crankshaft and bearings, connecting rods and bearings) can result in alteration of wear patterns that may increase wear or actually cause wear to start and decrease the life of the component. The period following overhaul is a "shakedown" period that is required to produce a reliable engine. Utilities have and will continue to minimize this impact by performing "break in" runs per the manufacturer recommendations; however, the "shake down" period extends well beyond the break in run time. The Owners Group agrees with the findings of the above studies.

The results of the 5 year "mini" teardowns have shown no component failures or degradation that resulted in a loss of component function. In addition, these overhauls have shown that operational component wear since installation has been minimal. All plants listed have completed the 5 year "mini" teardown for their engines with the exception of Comanche Peak and Bellefonte.

To perform a complete overhaul for a typical engine takes approximately six weeks during an outage. This increases diesel unavailability significantly. Since diesel unavailability is a major contributor to shut down risk this results in an overall decrease in plant shutdown safety margin.

Extending the period between overhauls offers a number of safety and economic advantages. First, it reduces the cost incurred for parts and labor to replace or refurbish components that have minimal wear (parts replaced under the current maintenance program are in "like new" condition due to limited engine operating hours). Second, it increases the reliability of the engine by eliminating the break-in period after overhaul. Finally, engine availability during outages is increased. In order to obtain these benefits the Owner's Group requests that an overhaul frequency not be specified and the utilities be allowed to determine when an overhaul is required based on engine surveillance and operating parameter trending.

Maintenance has and will continue to be performed as required by the Owners. The owner's maintenance requirements are addressed in each plant's Technical Specifications. Current Technical Specification requirements are summarized in Table 2. A revision to the maintenance program is underway. This revision is being developed in conjunction with the vendor and will provide additional guidance to member utilities on when inspection and other maintenance is really required for the engines.

3.0 COMPONENTS TO BE REVIEWED

This submittal will address the specific components listed below:

turbochargers

main bearing/caps/studs

cylinder block

connecting rods/bearing bushings

cylinder heads

push rods

lower cylinder liner seals

base assembly

crankshaft

cylinder liners

pistons/rings

fuel injection tubing

rocker arm capscrews/drive studs

These components form the principle "power cylinder" structure for the engine and are the typical components that are inspected and/or replaced during an engine overhaul. These items also require the longest time period to disassemble and are the most costly to replace. While other components would certainly be inspected if an engine were to undergo a teardown, intrusive disassembly of a power cylinder (removal of head, piston, bearings, connecting rods, etc) is a major concern since the affected components form the power train. Any problems on these components resulting from the intrusive inspections would certainly limit or preclude acceptable power output of the engine. Disassembly of these components offers the opportunity to introduce dirt and other foreign materials that may harm the engine. In addition, these components are assembled with the precision fit mating surfaces. Disturbance of these fits can cause different wear patterns to develop resulting in accelerated wear and shortened component life.

These components formed the basis of the original Phase I DR/QR component review for the above reasons. In addition, inspections of these components have been the focus of subsequent teardowns and provided the detailed data presented in this report. Lower liner seals were added to the list due to concerns raised during review of a prior submittal.

The Owners Group believes that addressing these components will provide a sufficient basis for permitting the overhaul frequency to be left to the discretion of the utilities.

4.0 COMPONENTS

4.1 MP-022/23 Turbochargers

BACKGROUND

Overall turbocharger experience for the Enterprise engines has been very good. While some problems have occurred, (e.g. missing stationary vanes) there have been no turbocharger failures reported which impacted engine performance. Problems associated with turbochargers and the resolutions are presented below.

Lubrication and Bearing Wear-- To address bearing wear issues the Owners have implemented modifications to install drip and full flow pre-lubrication systems. These systems provide an oil film to the turbo bearings during standby conditions and are used to prelube the turbochargers prior to a planned start. In addition, the Owner's oil sampling program provides a means of detecting metallic particles that would be an early indication of bearing wear. Finally, inspection results show (Table 1, Component MP-022/023) that significant bearing wear has not affected turbocharger performance.

Stationary Vanes Issues -- Four engines have found missing stationary vanes at the turbocharger inlet . Upon subsequent inspection, minor pitting was found on the rotating vane group but no turbocharger failure nor degraded performance has resulted.

OVERHAUL

An overhaul of the turbocharger would typically address the following items:

1) Measure vibration and check with baseline data.

2) Inspect impeller/diffuser and clean if necessary.

3) Measure rotor end play (axial clearance) to identify trends of increasing clearance.

4) Perform visual and blue check inspections of the thrust bearing.

5) Disassemble, inspect, and refurbish.

6) The nozzle ring components and inlet guide vanes should be visually inspected for missing parts or parts showing distress.

7) Monitor inlet temperature to ensure gas temperature does not exceed manufacturer's recommendation of 1200°F if exhaust temperature for any cylinder exceeds 1050°F.

DATA

Note that there are a total of 38 turbochargers in service from a total of 20 engines.

Item 1

Not applicable.

Item 2

There have been 55 inspections performed. The average run time is 600 hours and the average number of starts is 200. No adverse findings were noted from the inspections.

Item 3

There have been 108 inspections performed. The average run time is 600 hours and the average number of starts is 200. No adverse findings were noted from the inspections.

Item 4

There have been 61 inspections performed. The average run time is 600 hours and the average number of starts is 300. No adverse findings were noted from the inspections.

Item 5

There have been 58 inspections performed. The average run time is 600 hours and the average number of starts is 300. No adverse findings were noted from the inspections.

Item 6

There have been 70 inspections performed. The average run time is 600 hours and the average number of starts is 200. Four engines have reported finding missing vanes but did not produce a degradation of engine performance. No adverse findings were noted from the inspections.

Item 7

Not applicable.

CONCLUSIONS

No adverse findings have been noted during turbocharger inspections. In addition, no engine failures due to turbocharger performance have been recorded. A review of inspection data results indicates that periodic overhaul of the turbocharger is required. The inspection 38 turbochargers provides a well documented basis for determining the appropriate overhaul frequency. These inspection results coupled with an understanding of the impact of bearing wear on engine performance, installation of pre-lube systems to limit wear and the availability of effective monitoring techniques will allow the Owners to determine when turbocharger overhaul is required. In general the data would indicate an overhaul frequency of once every five years. Similar data for non-nuclear engines show a need to overhaul turbochargers every 8000 to 10000 hours.

4.2 02-305A Base Assembly

BACKGROUND

The original Owners Group review in the DR/QR report found adequate factors of safety in the design of this component. Problems with this component were on non nuclear service engines and were a result of inadequate bolt preload and in one case, marginal strength due to an inferior quality casting. Subsequent testing and/or inspections have been made by the Owners to confirm quality castings and the absence of cracking. In addition, steps have been taken to ensure adequate bolt preload.

OVERHAUL

An overhaul for the base assembly would address the following item:

- Perform a visual inspection of the base.

DATA

Note that there are a total of 20 engine bases in service on a total of 20 engines.

There have been 52 inspections performed. The total (average) hours logged is 900 and the average number of starts is 400. No adverse findings were noted from the inspections. This represents 90% of the total population of bases inspected.

CONCLUSIONS

Approximately 90 % of the nuclear service engine bases have been inspected. These inspections were conducted with significant operating hours and starts and are representative of all operating nuclear service engines. No adverse findings have been reported. These inspection results coupled with previous Owners Group work show that the base has an infinite life. Specifically, PNL-5600, 4.12.3.2.1 notes the FAA work, "All components of the base assembly have sufficient strength to operate indefinitely at full load, provided that the base casting and bolting components meet their nominal material and dimensional specifications, that the components have not been damaged, and the bolt torque specifications are maintained." As noted above, sufficient positive inspections/tests have been completed to show that the casting and bolt specifications are adequate. On this basis eliminating time based inspection of this component is appropriate. This component should be expected to perform satisfactorily for the 40 year station life without overhaul. Similar experience with non nuclear engines shows an infinite life expectancy.

4.3 02-305C Main Bearing Caps/Studs

BACKGROUND

Few problems have ever been found regarding bearing caps and studs. Previous Owners Group work has shown that the caps have a factor of safety against fatigue failure of 2.42 and the main saddles have a factor of safety against fatigue failure of 1.75 (PNL-5600, Section 4.12.3) One problem that was found at Shoreham was in cracking in the main bearing cap stud holes. This problem was caused by the stud removal method. (PNL-5600, Section 4.12.3.2.1.)

OVERHAUL

An overhaul of the main bearing caps, studs and nuts would address the following item:

- The mating surfaces at the bearing cap/saddle interface should be inspected when disassembled to ensure the absence of surface imperfections that might prevent tight boltup.

DATA

Note that there are 200 main bearing caps in service on a total of 20 engines.

There have been 108 inspections of caps, studs, and nuts performed. The total (average) hours logged is 1000 and the average number of starts is 490. No adverse findings were noted from the inspections. This represents 50% of the total population of bearing caps, studs and nuts inspected.

CONCLUSIONS

50% of the population of these components currently in service have been inspected. This sample is representative of all nuclear engines at operating facilities. All inspections were conducted with at least 600 hours of operation. A number of inspections have been performed on engines with more than 2000 hours of operation. No adverse findings have been noted during these inspections. Based on the high safety factors and significant, positive inspection experience, it is concluded that these components should not require overhaul for the 40 year life of the station. Manufacturers information indicates that this component has an infinite life expectancy for non nuclear engines .

4.4 02-310A Crankshaft

4.4.1 DSR-48 Series Engines

BACKGROUND

The only utility with this series engine is the River Bend station. The EDG engines at River Bend have crankshafts with the same dimensions as the replacement shafts at Shoreham. However, the generators and flywheels differ between the two installations, resulting in differences in crankshaft torsional stresses. Also the crankshaft fillets at Shoreham are shotpeened while those at River Bend are not. A complete analysis of the Shoreham replacement crankshaft has shown it to have an infinite life under nuclear service operating conditions. Comparison of the crankshaft torsional stresses in the Shoreham engines at an operational load of 3300 kw to the torsional stresses in the River Bend engines at an operational load of 3130 kw shows that the torsional stresses are equivalent at these respective loads. Therefore, the River Bend engines have been derated for nuclear service. The analysis demonstrates infinite fatigue life for the River Bend crankshafts at loads under 3130 kw (Reference PNL-5600, 4.6.7.2)

OVERHAUL

An overhaul of the crankshaft would address the following items:

1) Measure and record crankshaft web deflections. (hot and cold)

2) Examine the fillets and oil holes in two of the three crankpin journals (5,6,7) using liquid penetrant.

3) Examine the fillets and oil holes of the two main bearing journals between crankpin journals Nos. 5, 6 and 7 using liquid penetrant.

4) Measure the diameter of crankpin journals.

DATA

There are two crankshafts of this type in two engines.

Item 1

Not applicable.

Item 2

There have been 9 inspections performed. The average run time is 820 hours and the average number of starts is 270. No adverse findings were noted from the inspections.

Item 3

There have been 7 inspections performed. The average run time is 760 hours and the average number of starts is 270. No adverse findings were noted from the inspections.

Item 4

There have been 4 inspections performed. The average run time is 760 hours and the average number of starts is 275. No adverse findings were noted from the inspections. This represents 25% of the total population of crankpin journals inspected.

CONCLUSIONS

A significant number of fillets, oil holes and journals have been inspected on the DSR engines. The inspections were conducted with over 700 hours and 270 starts with no adverse findings. The River Bend engines have been derated and are operated at less than 3130 kw at all times. Based on the analysis (Reference PNL-5600, 4.6.7.2), engine operational power limits and the inspection results, overhaul of the River Bend crankshafts should not be required over the life of the station. Manufacturer's information on non nuclear engines indicate an infinite life expectancy for the crankshaft.

4.4.2 DSRV-16 Series Engines

BACKGROUND

The DSRV-16 crankshafts at each site have been independently evaluated to determine the impact of torsional stresses on the life of the component. No problems have ever been identified on this component. The Owners Group and PNL analysis (PNL-5600, Section 4.7) show an infinite fatigue life for these components. Thirteen of the eighteen engines in nuclear service have operating hours which exceed the calculated fatigue limit for the crankshaft.

OVERHAUL

An overhaul of the crankshaft would address the following items:

1) Measure and record crankshaft web deflections. (hot and cold)

2) Examine the fillets and oil holes of three main bearing journals (4,6,8) using liquid penetrant.

3) Examine the fillets and oil holes in three of the crankpin journals (choose 3 from Nos. 3 through 8 inclusive) using liquid penetrant.

4) Measure the diameter of crankpin journals.

DATA

There are eighteen of these components in service in eighteen engines.

Item 1

Not applicable.

Item 2

There have been 32 inspections performed. The average run time is 1000 hours and the average number of starts is 500. No adverse findings were noted from the inspections. This represents 25 % of the total population of crankshafts inspected.

Item 3

There have been 45 inspections performed. The average run time is 1100 hours and the average number of starts is 500 No adverse findings were noted from the inspections.

This represents 25% of the total population of crankshaft fillets inspected.

Item 4

There have been 44 inspections performed. The average run time is 1000 hours and the average number of starts is 500. No adverse findings were noted from the inspections. This represents 25% of the total population of crankpin journals inspected.

CONCLUSIONS

Approximately 25% of the oil holes, fillets and journals have been inspected on the DSRV-16 crankshafts. The minimum number of hours at inspection was more than 700 while several inspections were done on engines with more than 2000 hours of operation. More than 70 % of the engines have operated such that the calculated fatigue limit of the crankshaft has been validated. The DSRV-16 engines are operated within the design limits of 100% power to 110% power. When operated in this manner the crankshaft has been shown to have an infinite fatigue life. Based on operating power limits, infinite fatigue life and the positive inspections conducted with significant operating hours, this component would not be expected to require an overhaul within the 40 year operating life of the station.

4.5 02-315A Cylinder Block

BACKGROUND

A thorough design review of this component was completed during the initial DR/QR review. This review showed that some castings fabricated during the period when the Owner's engines were manufactured could contain Widmanstaetten graphite. Widmanstaetten graphite is an inclusion that weakens the grey iron casting. It was shown that blocks containing this material have a greater potential for developing cracks. However, it was also shown that should these cracks develop for any reason they would not impact the block's to perform its intended design function. Analysis indicated that cracks would be expected to arrest without any impact on block performance. However, if the worst case scenario of crack propagation is assumed, it was shown that the flow path for water would be to the block exterior. This degradation would not impact engine performance and would be readily detectable. A cumulative fatigue usage index formula was created and an inspection frequency was established based on that usage factor. Further, it was noted by the Owner's Group and by the NRC that this analysis was conservative. PNL 5600 states "If cumulative results of these inspections over several power plant fuel cycles show that one or more of the inspections reveal nothing of significance, the scope and frequency of the inspections could be reconsidered." (Source PNL-5600, Section 4.9.5.2)

OVERHAUL

An overhaul of the block would typically address the following item:

- Perform visual inspection for cracks.

DATA

There are currently 20 of these components in service in twenty engines.

There have been 129 inspections performed. The average run time on this component is 1000 hours and the average number of starts is 400. No adverse findings were noted from the inspections. This represents 90% of the total population of blocks inspected.

CONCLUSIONS

All engines currently in nuclear service have had block top inspections performed all with more than 600 hours of operation. No block cracking has been identified. Based on a design analysis which shows that cracking does not impact component performance and inspection results with the significant accumulated operating hours, it can be expected that this component will operate the life of the plant without overhaul. Non nuclear experience with this component indicates an infinite life expectancy. Based on the PNL 5600 information (PNL-5600, Section 4.9.5.2), design analysis and inspection results to date it is concluded that this inspection is not required.

4.6 02-315C Cylinder Liners

BACKGROUND

The initial review of cylinder liner design revealed no major concerns. The only concern identified was potential cylinder liner wear. Inspections of liners in nuclear service have shown minimal wear. Recent 10CFR21 reports have highlighted that liners installed with a "loose fit" as originally prescribed by TDI and FaAA are subject to some initial motion until the liner is thermally heated and expands tight against the block. This has resulted in some reported cracking on non nuclear engines and on at least one nuclear engine. The vendor resolution to this item is that the liners with "loose fit" are acceptable for service up to 3000 operating hours and at that point should be inspected and/or replaced with the "tight fit" liners. During recent inspections at one nuclear facility 2 liners were replaced due to scuffing. This scuffing was result of carbon build up on the rings. The root cause of this carbon build up is thought to be an excessive fuel condition experienced during fast starts. This problem is still under investigation.

OVERHAUL

An overhaul of the liner would address the following item:

1) Perform a visual inspection of liners for progressive wear and cracking.

2) Per 10CFR21, an inspection for cracking and/or replacement will be made.

DATA

There are 304 liners currently in service in 20 engines.

Item 1

There have been 840 inspections performed. The average run time is 900 hours and the average number of starts 400. One finding of a cracked liner has been reported and is addressed by the 10CFR21 resolution. Two cylinder liners with scuffing were identified on one engine. No other findings have been identified.

Item 2

Inspection per 10CFR21 have begun. Results are not currently available on this item.

CONCLUSIONS

The only finding thus far has been the indication of crack at one nuclear utility and liner scuffing at another. While the analysis has shown this component satisfactory for station life, to address potential liner cracking, vendor recommendations for inspection and/or replacement of liners at or prior to 3000 operating hours will be followed unless other engineering evaluations performed show that this inspection and/or replacement is not required. The liner scuffing problem is still under investigation. A remedial program to address this concern will be developed by the Owner's in concert with the engine manufacturer. Future overhaul intervals/inspections will be evaluated based on additional analysis and experience. Non nuclear users normally run engines for 55,000 hours prior to replacing this component. It is concluded that the cylinder inspection requirement should be deleted. The basis for this conclusion is two fold. First, there have been significant inspections of this component with no problems identified. Second, the Owner's and manufacturer have proactive remedial programs underway to address the two concerns identified. Any maintenance, overhaul or inspections required to address these issues will be included in the Owner's maintenance programs.

4.7 023-40A/B Connecting Rods/Bearings/Bushings

4.7.1 DSR Series Engines

BACKGROUND

No problems have been found with the in line series connecting rods. The design review found factors of safety in the design calculations in excess of 5.0 for critical loadings (PNL-5600, Section 4.3.3.2.3.)

OVERHAUL

An overhaul of the connecting rod would address the following items:

1) Inspect and measure all connecting rod bearing shells to verify lube oil maintenance, which affects wear rate.

2) Inspect and measure the connecting rods.

3) Perform an x-ray examination on all replacement bearing shells to acceptance criteria developed by Owners Group Technical Staff.

4) All connecting rod bolts,nuts, and washers should be visually inspected, and damaged parts should be replaced. The bolts should be MT inspected to verify the continued absence of cracking. No detectable cracks should be allowed at the root of the threads.

5) During any disassembly that exposed the inside diameter of a rod-eye (piston pin) bushing, the surface of the bushing should be LP inspected to verify the continued absence of linear indications in the heavily loaded zone width +/- 15 degrees of the bottom dead center position.

DATA

There are 16 in line connecting rods in service in two engines.

Item 1

There have been 6 inspections performed. The average run time is 700 hours and the average number of starts is 275. No adverse findings were noted from the inspections. This represents 35% of the total population of connecting rods inspected.

Item 2

There have been 4 inspections performed. The average run time is 700 hours and the average number of starts is 275. No adverse findings were noted from the inspections. This represents 25% of the total population of connecting rods inspected.

Item 3

Not applicable. X-ray examination of bearing shells was addressed in a previous communication to the NRC.

Item 4

There have been 52 inspections performed. The average run time is 700 hours and the average number of starts is 275. No adverse findings were noted from the inspections.

Item 5

There have been 4 inspections performed. The average run time is 700 hours and the average number of starts 275. No adverse findings were noted from the inspections. This represents 25% of the total population of connecting rods inspected.

CONCLUSIONS

25% of these components in nuclear service have been inspected with no adverse findings. Based on the large design factors of safety and the minimum wear exhibited after more than 700 hours of operation, it is projected that this component will last the 40 year life of plant without overhaul. Non nuclear users normally run engines 50,000 hours prior to rod replacement with bushings replaced at 35,000 hours. It is concluded that inspection of these components is not required based on large factors of safety in the design and extensive positive inspections.

4.7.2 DSRV-16 Series Engines

BACKGROUND

Problems have been found on DSRV articulated connecting rods with 1- 1/2" bolts. These problems were discovered prior to the use of the DSRV engines in nuclear service and during the early start up periods for the nuclear engines. The root cause of these problems was inadequate connecting rod bolt preload. The Owners Group consultants proposed the measurement of connecting rod preload using an ultrasonic stretch measurement technique. This technique is more accurate than measuring torque and can be used to determine if any bolt relaxation or cracking has taken place without disassembly. This ultrasonic preload measurement methodology was adopted by the Owners. Since the implementation of this technique no connecting rod problems have been reported.

One utility was supplied with connecting rods with 1 7/8" bolts. Analysis has indicated that at 100% design load, these bolt loads are slightly above the fatigue initiation stress. (Reference FaAA report FaAA-84-3-14) This work indicated that these bolts are satisfactory as long as they are properly torqued and the engine operating load is limited such that connecting rod stresses remain below the fatigue initiation curve. Operating load for this engine has been limited to ensure that this condition is met. Ultrasonic preload measurement is also used to ensure proper bolt loading.

OVERHAUL

An overhaul of this component would address the following items:

1) Inspect and measure all connecting rod bearing shells to verify lube oil maintenance, which affects wear rate.

2) Inspect and measure the connecting rods.

3) Perform an x-ray examination on all replacement bearing shells to acceptance criteria developed by Owners Group Technical Staff.

4) All connecting rod bolts/studs, nuts, and washers should be visually inspected, and damaged parts should be replaced. The bolts should be MT inspected to verify the continued absence of cracking. No detectable cracks should be allowed at the root of the threads.

5) During any disassembly that exposed the inside diameter of a rod-eye (piston pin) bushing, the surface of the bushing should be LP inspected to verify the continued absence of linear indications in the heavily loaded zone width +/- 15 degrees of the bottom dead center position.

6) Measure the clearance between the link pin and link rod. This clearance should be zero; i.e. no measurable clearance when the specified bolt torque of 1050 ft-lbs is applied.

7) Visually inspect the rack teeth surfaces for signs of fretting.

8) Inspect mating surfaces to verify that the minimum manufacturers' recommended percent contact surface is available.

9) Measure bolt stretch prior to disassembly to denote if any relaxation has occurred.

10) All connecting rod bolts/studs should be visually inspected for thread damage (galling) and the two pairs of connecting rod bolts/studs above the crankpin should be MT inspected to verify the absence of cracking. All washers used with the bolts/studs should be examined visually for signs of galling or cracking and replaced if damaged. If prestessor package is installed, this does not apply.

11) A visual inspection should be performed of all external surfaces of the link rod box to verify the absence of any signs of service induced distress.

12) All of the bolt holes in the link rod box should be inspected for thread damage (galling) or other signs of abnormalities. Bolt holes subject to the highest stresses (the pair immediately above the crankpin) should be examined with an appropriate nondestructive method to verify the absence of cracking. Any indications should be recorded for evaluation and corrective action. If prestressor package is installed, this item does not apply.

DATA

There are 144 pairs of articulated connecting rods in service in 18 engines. These rods have associated with them 864 bolts/studs and nuts. There are a total of 288 link rod box threaded holes.

Item 1

There have been 55 inspections performed. The average run time 1000 hours and the average number of starts is 500. No adverse findings were noted from the inspections. This represents 39% of the total population of connecting rods inspected.

Item 2

There have been 68 inspections performed. The average run time is 1100 hours and the average number of starts is 500. No adverse findings were noted from the inspections.

Item 3

Not applicable. X-ray examination of bearing shells was addressed in a previous communication to the NRC.

Item 4

There have been 260 inspections performed. The average run time is 900 hours and the average number of starts is 500. No adverse findings were noted from the inspections.

Item 5

There have been 69 inspections performed. The average run time is 900 hours and the average number of starts is 500. No adverse findings were noted from the inspections.

Item 6

There have been 94 inspections performed. The average run time between is 1000 hours and the average number of starts is 300. No adverse findings were noted from the inspections.

Item 7

There have been 63 inspections performed. The average run time is 1000 hours and the average number of starts is 500. No adverse findings were noted from the inspections. T

Item 8

There have been 66 inspections performed. The average run time is 1000 hours and the average number of starts 300. No adverse findings were noted from the inspections.

Item 9

There have been 1290 inspections performed. The average run time is 1100 hours and the average number of starts is 500. No adverse findings were noted from the inspections.

Item 10

There have been 290 inspections performed. The average run time is 1000 hours and the average number of starts is 500. No adverse findings were noted from the inspections.

Item 11

There have been 56 inspections performed. The average run time is 1000 hours and the average number of starts is 500. No adverse findings were noted from the inspections.

Item 12

There have been 106 inspections performed. The average run time ia 1000 hours and the average number of starts is 500. No adverse findings were noted from the inspections.

CONCLUSIONS

Extensive inspections of the areas of interest on connecting rod assemblies have been conducted without any adverse findings. The average number of hours on the engine at time of inspection was more than 900 hours. Sever . engines had more than 2000 hours at the time of inspection. All utilities have implemented the use of ultrasonic preload measurement. For the 1-1/2 " bolts adequate margin against fatigue has been shown to exist at engine design load. The one utility with engines using the 1 7/8 " bolts has instituted engine operating load limits to ensure that fatigue failure is precluded. Based on the design margins, the use of ultrasonic preload measurement. an operating load limit for engines with 1 7/8 " bolts and the inspection results, this component can be expected to last the 40 year plant life without overhaul.

Non nuclear users typically run engines 50,000 hours prior to replacement of this component and 35,000 hours prior to replacing the rod eye bushing.

4.8 02-341A Pistons/Rings

BACKGROUND

All nuclear users have installed the AE model piston skirts. These piston skirts have previously been qualified at the rated engine load and have been validated for their fatigue life on 13 of the 20 engines in service. Analysis of the AE piston skirt design margin against fatigue (PNL-5600, Section 4.16.3) supports the Owners Group engine qualification findings.

OVERHAUL

An overhaul of the pistons and rings would address the following item:

- Inspect and measure the skirt and piston pin.

DATA

There are currently 304 pistons in service in 20 engines.

There have been 91 inspections performed. The average run time is 800 hours and the average number of starts is 500. No adverse findings were noted from the inspections.

This represents 25% of the total population of pistons inspected.

CONCLUSIONS

Pistons and rings have been one of the more reliable components in nuclear service. 25% of the pistons in nuclear service have been inspected. Some inspections have been conducted with more than 2000 hours of operation. Inspections have revealed no stress related or any wear related concerns. Based on the number of hours logged in service, the positive inspection results and the design margin it is expected that the AE piston skirts and rings to run the 40 year life of plant prior to overhaul. . Non nuclear users typically run engines 60000 hours prior to replacing pistons and 20,000 hours prior to replacing rings.

4.9 02-360A Cylinder Heads

BACKGROUND

Cylinder heads for the DSR-48 series and DSRV-16 series engines are similar in design and are addressed as one component. Cylinder heads are designated as either Group I, II, or III. . These groupings identify three distinct periods of design and design/fabrication control. These periods are marked by changes in the casting and fabrication of the heads and in the weld techniques used to repair the heads. Some of all three groups of heads remain in nuclear service today. PNL-5600, Section 4.10.3.3 concluded that all groups of heads are adequate for their intended service. Any cracks which develop would not be detrimental to engine performance. The flow path of water resulting from a crack would be to the exterior of the engine which would be readily detected and would allow the head to be repaired or replaced. As an added precaution against cylinder head cracking, air rolling of the engine with the indicator cocks open is used at all sites to check for potential in leakage of water. Cylinder head cracking or water in leakage has been observed. A previous 10CFR21 notification regarding leakage through a small thinned area has been evaluated and a program to address the problem has been implemented. This is documented in the response to the notification.

OVERHAUL

An overhaul of the heads would address the following items:

1) Visually inspect cylinder heads.

2) Record cold compression pressures and maximum firing pressures

3) Blow-over the engine at least 4 hours but not more than 8 hours after engine shutdown.

4) Visually inspect the area around the fuel injection port on each cylinder head during the normal monthly run for signs of leakage.

DATA

There are currently 304 heads in nuclear service on 20 engines.

Item 1

There have been 498 inspections performed. The average run time is 1000 hours and the average number of starts is 400. No adverse findings were noted from the inspections.

Item 2

Not applicable.

Item 3

Not applicable.

Item 4

Not applicable.

CONCLUSIONS

There have been extensive inspections of this component. The average operating hours on the cylinder heads is 1000 and some heads have operated more than 2000 hours. No cylinder head cracking has been identified which has caused a loss of engine performance. Based on the large number of operating hours, and the positive inspection results, this component is expected to last the 40 year plant life without needing overhaul. Non nuclear users typically run their engines 35,000 hours prior to performing an overhaul of this type component.

4.10 02-365C Fuel Injection Tubing

BACKGROUND

A 10CFR21 notification was issued on 7/20/83 by TDI alerting Owners and the NRC of a condition that may cause failure of the tubing. This condition results from a draw seam that acts as a stress riser on the inner surface of the tube. The draw seam is induced during the drawing phase of the manufacturing and generally will extend over most of the length of the tube and is readily detectable. The review noted the tubing is acceptable as long as no preexisting flaws greater than a depth of .0054" existed. This prompted the recommendation to eddy current the tubing prior to bending and install replacement tubing that had been eddy current tested or of the new shrouded tubing design (tube within a tube). The reasons for the concern are the potential for fire resulting from a broken tube and a personnel safety issue due to a high pressure fuel oil leak.

OVERHAUL

An overhaul of this component would address the following items:

1) Check tubing for leaks at compression fittings.

2) Visually inspect tubing lengths for fuel oil leaks or cracks if tubing is unshrouded. If shrouded, fuel oil leakage can be detected at the leak-off ports in the base nuts, which are provided for this purpose, or by annunciator, if so equipped.

DATA

There is multiple footage of tubing on any particular engine with numerous fittings. The number is dependent on tubing routing and room layout.

Item 1

Not Applicable.

Item 2

There have been more than 3000 inspections performed. The average run time is approximately 700 hours and the average number of starts is 300. No adverse findings were noted from the inspections.

CONCLUSIONS

Based on the service of this component and the ease of inspection for leaks during operation, overhaul of this component is unnecessary. However, life of each fitting and tube assembly cannot be assured over the 40 year life depending on vibration maintenance loads, etc. While actual overhaul is not required, periodic inspections should be formed in order to monitor tubing for leakage and repair as required. Commercial engine life for this component is approximately 35,000 hours.

4.11 02-390C Push Rods

BACKGROUND

Major problems with this component resulted from a previous TDI design which is no longer in use by nuclear utilities. Nuclear engines currently employ the friction welded design. The performance of this design in nuclear service has been excellent. A design fatigue and a buckling evaluation has shown acceptable factors of safety for this component.

OVERHAUL

An overhaul of the push rod would typically address the following items:

1) The push rod should be visually inspected for cracks. A one time inspection using liquid penetrant was required.

2) Each push rod of the friction-welded design should be inspected initially by liquid penetrant. If this initial inspection was not performed prior to placing the push rods in service, it should be performed at the first overhaul. If the friction-welded push rod has been previously inspected by liquid penetrant, then visual examination will suffice for future inspections. All friction-welded push rods with cracks should be replaced, preferably with push rods or the same design.

DATA

There are a total of 912 push rods currently in service is 20 engines.

Item 1

Not Applicable.

Item 2

There have been greater than 116 inspections performed. The average run time is approximately 800 hours and the average number of starts is 300. No adverse findings were noted from the inspections.

CONCLUSION

Since replacement with an enhance design problems have been identified with push rods. Based on the design margins, significant number of operating hours and number of inspections, this component should achieve the 40 year life without an overhaul inspection. Non nuclear users typically run engines for 100,000 hours prior to replacement.

4.12 02-390G Rocker Arm Capscrews/Drive Studs

BACKGROUND

The review during the initial DR/QR revealed that capscrews failures had occurred on an isolated basis. The cause of the failures was due to insufficient preload on the capscrews. The Owners Group preformed a detailed design review of the component. This review calculated appropriate resultant stresses, endurance limits, and evaluated the material requirements to ensure that the material was suitable. PNL-5600, Section 4.18.4.3 notes, "If the rocker arm capscrews are installed with the proper preload, they should not require any maintenance/surveillance until they are removed for other reasons."

OVERHAUL

An overhaul of the rocker arm capscrews would address the following item:

1) Verify capscrew torque values upon reassembly.

2) Verify that rocker arm drive studs are intact and tight at reassembly.

DATA

There are numerous rocker arm capscrews in service for 20 engines.

Item 1

There have been 91 inspections performed. The average run time is approximately 700 hours and the average number of starts is 270. No adverse findings were noted from the inspections.

Item 2

There have been 183 inspections performed. The average run time is approximately 800 hours and the average number of starts is 270. No adverse findings were noted from the inspections.

CONCLUSIONS

The Owners have emphasized elimination of the cause of the original capscrew failures. Capscrew installation procedures address ensuring proper preload. This approach has eliminated capscrew failures. Based on the inspection results and the adequate design margins identified this component should not need overhaul during the 40 year life of the plant.

4.13 Lower Liner Seals

BACKGROUND

The lower liner seals are an elastomeric O ring that forms a seal between the liner and block assembly. This seal prevents the mixing of engine cooling water or jacket water with lube oil. The seals are made of viton which has an excellent record of service in such applications. There are three seals for each cylinder which provides multiple barriers in the unlikely event of one of the seals failing.

OVERHAUL

This is an inexpensive item which requires replacing once a cylinder liner is removed from the engine.

DATA

There are 912 seals in service in 20 engines.

Item 1

There have been 84 inspections performed. The average run time is 200 hours and the average number of starts is 100. No adverse findings were noted from the inspections.

CONCLUSIONS

The concern for engine owners is that engine disassembly for replacement of the liner seals on a time dependent basis is costly and unnecessary. Monitoring of the oil and jacket water levels provides an alternate means for determining whether these seals need replacing. A significant number of inspections of these seals have been conducted with no degradation identified. In addition, the multiple seal design provides added protection against seal failure which would actually impact engine performance Based on the failure monitoring capability, the multiple seal design and positive inspection results, the lower liner seals do not need replacement during the 40 year life of the plant unless the liner is removed for other reasons. This conclusion is supported by Cooper based on their non nuclear and nuclear engine experience.

inspection. Non nuclear users typically run engines for 100,000 hours prior to replacement.

4.12 02-390G Rocker Arm Capscrews/Drive Studs

BACKGROUND

The review during the initial DR/QR revealed that capscrews faiiures had occurred on an isolated basis. The cause of the failures was due to insufficient preload on the capscrews. The Owners Group preformed a detailed design review of the component. This review calculated appropriate resultant stresses, endurance limits, and evaluated the material requirements to ensure that the material was suitable. PNL-5600, Section 4.18.4.3 notes, "If the rocker arm capscrews are installed with the proper preload, they should not require any maintenance/surveillance until they are removed for other reasons."

OVERHAUL

An overhaul of the rocker arm capscrews would address the following item:

1) Verify capscrew torque values upon reassembly.

2) Verify that rocker arm drive studs are intact and tight at reassembly.

DATA

There are numerous rocker arm capscrews in service for 20 engines.

Item 1

There have been 91 inspections performed. The average run time is approximately 700 hours and the average number of starts is 270. No adverse findings were noted from the inspections.

Item 2

There have been 183 inspections performed. The average run time is approximately 800 hours and the average number of starts is 270. No adverse findings were noted from the inspections.

CONCLUSIONS

The Owners have emphasized elimination of the cause of the original capscrew failures. Capscrew installation procedures address ensuring proper preload. This approach has eliminated capscrew failures. Based on the inspection results and the adequate design margins identified this component should not need overhaul during the 40 year life of the plant.

4.13 Lower Liner Seals

BACKGROUND

The lower liner seals are an elastomeric O ring that forms a seal between the liner and block assembly. This seal prevents the mixing of engine cooling water or jacket water with lube oil. The seals are made of viton which has an excellent record of service in such applications. There are three seals for each cylinder which provides multiple barriers in the unlikely event of one of the seals failing.

OVERHAUL

This is an inexpensive item which requires replacing once a cylinder liner is removed from the engine.

DATA

There are 912 seals in service in 20 engines.

Item 1

There have been 84 inspections performed. The average run time is 200 hours and the average number of starts is 100. No adverse findings were noted from the inspections.

CONCLUSIONS

The concern for engine owners is that engine disassembly for replacement of the liner seals on a time dependent basis is costly and unnecessary. Monitoring of the oil and jacket water levels provides an alternate means for determining whether these seals need replacing. A significant number of inspections of these seals have been conducted with no degradation identified. In addition, the multiple seal design provides added protection against seal failure which would actually impact engine performance Based on the failure monitoring capability, the multiple seal design and positive inspection results, the lower liner seals do not need replacement during the 40 year life of the plant unless the liner is removed for other reasons. This conclusion is supported by Cooper based on their non nuclear and nuclear engine experience.

SAMPLE DATA TABLE (annotated)

ATTACHMENT II

12/4/93

Results of Inspection for TDI D/G Phase I Components

Component No.	PM No.	Utility Results	D/G Train	No. Inspections	Run Hours	No. Starts
MP-022/23	6	Turbocharger		Manf Recom O/H Hrs:	8000-10000	
The nozzle ring components and inlet guide vanes should be visually inspected for missing parts of parts showing distress. If such conditions are noted, the entire ring assembly should be replaced						
		CP&L		5	615	325
		ATAWB SAT		10	136	155
		DPC CATAWBA	2A			
		fiscovered on the right bank turbo ic turbo failures due to this conditic … een no				
		DPC CATAWBA	2B	8	152	163
		One missing vane was discovered on the right bank turbo during one inspection but there have been no instances of catastrophic turbo failures due to this condition.				
		PERRY SAT	1R43C001A/ 1R43C001B	2	42	34
			1EGS*EG1A			
			1R43C001A			
		GRAND GULF SAT	1A/DIV1			
		PERRY SAT	1R43C001B	1	300	190
		VOGTLE SAT	1B	2	852	236
		VOGTLE SAT			673	180
		VOGTLE SAT			866	237
		TU ELECTRIC SAT			790	146
		TU ELECTRIC SAT	1EG1	1	678	99
		DPC CATAWBA	1A			
		One missing vane was discovered on the right bank turl … instances of catastrophic turbo failures due to this conc … een no				
		CP&L SAT	1DG E002			

MP-022/23:
Component number (DR/QR)

PM No.:
Preventive maintenance task number as defined in Appendix II of the DR/QR Revision 3.

Manf.Recom O/H Hrs:
Manufacturer's recommendations for commercial engines for component operation prior to overhaul/replacement

PM Description:
Brief description of PM task.

Utility Results:
Brief description of the inspection results. Satisfactory (SAT) indicates that no conditions were found which would have prevented the EDG from performing its intended function.

No. Starts:
For components that have been overhauled/replaced. No. Starts indicates the number of run hours logged prior to overhaul/replacement. for components which have not been replaced/overhauled e.g. crankshaft, block etc. No. Starts indicates the number of hours logged without an adverse finding.

Run Hours:
For components that have been overhauled/replaced, Avg Run Hours indicates the number of run hours logged prior to overhaul/replacement. For components which have not been replaced/overhauled e.g. crankshaft, block etc. Avg Run Hours indicates the number of hours logged without an adverse finding.

Number of Inspections:
Number of times the DR/QR task has been performed. (Broken down by component where applicable e.g. bolts, nuts, pins etc.)

DATA TABLE THIRTEEN COMPONETS

ATTACHMENT III

12/5/93

Results of Inspection for TDI D/G Phase I Components

Component No.	PM No.	Utility Results	D/G Train	No. Inspections	Run Hours	No. Starts
02-305A	1	Base Assembly		Manf Recom O/H Hrs:	infinite	
Perform a visual inspection of the base. The inspection should include the areas adjacent to the nut pockets of each bearing saddle and be conducted after a thorough wipe down of the surfaces, using good lighting						
		DPC CATAWBA SAT	1B	5	1436	931
		GRAND GULF SAT	1B/DIV 2	1	1077	345
		GRAND GULF SAT	1A/DIV I	1	1710	433
		DPC CATAWBA SAT	2B	4	792	652
		DPC CATAWBA SAT	2A	4	793	679
		CP&L SAT	1DG E003	4	615	325
		RIVER BEND SAT	1EGS*EG1A	4	907.5	366
		DPC CATAWBA SAT	1A	5	1496	858
		VOGTLE SAT	2A	2	673	180
		VOGTLE SAT	1B	3	852	236
		VOGTLE SAT	1A	3	866	237
		VOGTLE SAT	2B	2	560	133
		PERRY SAT	1R43C001A/ 1R43C001B	6	300	190
		CP&L SAT	1DG E002	4	891	426
		RIVER BEND SAT	1EGS*EG1B	4	746.2	247
		Totals:		**Sum:** 52	**Avg:** 914.31	**Avg:** 415.9

12/5/93

Results of Inspection for TDI D/G Phase I Components

Component No.	PM No.	Utility Results	D/G Train	No. Inspections	Run Hours	No. Starts
02-305C	1	Main Bearing Caps, Studs & Nuts		**Manf Recom O/H Hrs:**	Brg 35,000, Cap/Stud/Nut - Inf.	

The mating surfaces at the bearing cap/saddle interface should Ibe inspected when disassembled to ensure the absence of surface imperfections that might prevent tight bolt up.

Component No.	PM No.	Utility Results	D/G Train	No. Inspections	Run Hours	No. Starts
		DPC CATAWBA SAT	1A	3	605	739
		DPC CATAWBA SAT	1B	3	681	775
		GRAND GULF SAT	1A/DIV 1	16	1710	433
		GRAND GULF SAT	1A/DIV 1	16	2021	655
		GRAND GULF SAT	1A/DIV 1	16	2148	712
		GRAND GULF SAT	1B/DIV 2	16	1454	605
		DPC CATAWBA SAT	2B	3	609	652
		DPC CATAWBA SAT	2A	3	633	607
		CP&L SAT	1DG E003	8	615	325
		PERRY SAT	1R43C001A/ 1R43C001B	8	530	310
		VOGTLE SAT	1B	4	852	236
		CP&L SAT	1DG E002	6	725	355
		RIVER BEND SAT	1EGS*EG1B	4	746.2	247
		RIVER BEND SAT	1EGS*EG1A	2	786.75	299
		Totals:		**Sum:** 108	**Avg:** 1008.3	**Avg:** 496.4

Component No.	PM No.	Utility Results	D/G Train	No. Inspections	Run Hours	No. Starts
02-310A	2	Crankshaft		**Manf Recom O/H Hrs:**	infinite	

Examine the fillets and oil holes of three main bearing journals (4.6 &8) using LP. If indications are evident, a more thorough examination should be made using appropriate NDE methods.

Component No.	PM No.	Utility Results	D/G Train	No. Inspections	Run Hours	No. Starts
		DPC CATAWBA SAT	1B	3	1436	931

Results of Inspection for TDI D/G Phase I Components

Component No.	PM No.	Utility Results	D/G Train	No. Inspections	Run Hours	No. Starts
		GRAND GULF SAT	1B/DIV 2	3	1454	606
		GRAND GULF SAT	1A/DIV I	3	2148	712
		DPC CATAWBA SAT	2B	3	792	652
		DPC CATAWBA SAT	2A	3	793	679
		CP&L SAT	1DG E003	3	615	325
		VOGTLE SAT	1B	3	852	236
		DPC CATAWBA SAT	1A	3	1496	858
		CP&L SAT	1DG E002	7	725	355
		PERRY SAT	1R43C001A/ 1R43C001B	1	530	310
		Totals:		**Sum:** 32	**Avg:** 1084.1	**Avg:** 566.3

Component No.	PM No.	Utility Results	D/G Train	No. Inspections	Run Hours	No. Starts
02-310A	3	Crankshaft		**Manf Recom O/H Hrs:**	infinite	

Examine the fillets and oil holes of the crankpin journals (choose 3 from nos. 3 through 8 inclusive) using LP. If indications are evident, a more thorough examination should be made using appropriate NDE methods.

		GRAND GULF SAT	1B/DIV 2	6	1454	606
		GRAND GULF SAT	1A/DIV I	6	2148	712
		DPC CATAWBA SAT	2B	3	792	652
		DPC CATAWBA SAT	2A	3	793	679
		PERRY SAT	1R43C001A/ 1R43C001B	1	530	310
		VOGTLE SAT	1B	9	852	236
		CP&L SAT	1DG E003	3	615	325

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Results of Inspection for TDI D/G Phase I Components

Component No.	PM No.	Utility Results	D/G Train	No. Inspections	Run Hours	No. Starts
		DPC CATAWBA SAT	1A	3	1496	858
		DPC CATAWBA SAT	1B	3	1436	931
		CP&L SAT	1DG E002	8	891	426
		Totals:		Sum: 45	Avg: 1100.7	Avg: 573.4
02-310A	4	Crankshaft		Manf Recom O/H Hrs:	infinite	
Measure diameter of crankpin journals						
		CP&L SAT	1DG E003	5	615	325
		GRAND GULF SAT	1B/DIV 2	6	1077	345
		GRAND GULF SAT	1A/DIV 1	6	1710	433
		DPC CATAWBA SAT	2A	3	793	679
		DPC CATAWBA SAT	1B	3	1436	931
		VOGTLE SAT	1B	9	852	236
		PERRY SAT	1R43C001A/ 1R43C001B	1	530	310
		CP&L SAT	1DG E002	5	891	426
		DPC CATAWBA SAT	1A	3	1496	858
		DPC CATAWBA SAT	2B	3	792	652
		Totals:		Sum: 44	Avg: 1019.2	Avg: 519.5
02-310A	2.1	Crankshaft		Manf Recom O/H Hrs:	infinite	
Examine the fillets and oil holes in two of three crankpin journals (5,6,7) using LP. If indications are evident, a more thorough examination should be made using appropriate NDE methods. (River Bend only)						
		RIVER BEND SAT	1EGS*EG1B	9	746.2	247

Results of Inspection for TDI D/G Phase I Components

Component No.	PM No.	Utility Results	D/G Train	No. Inspections	Run Hours	No. Starts
		RIVER BEND SAT	1EGS*EG1A	4	907.5	299
		Totals:		Sum: 13	Avg: 826.85	Avg: 273

02-310A 3.1 Crankshaft **Manf Recom O/H Hrs:** infinite

Examine the fillets and oil holes of the two main bearing journals betweeen crank pin journals Nos. 5, 6 &7 using LP. If indications are evident, a more thorough examination should be made using appropriate NDE methods. (River Bend only)

RIVER BEND SAT	1EGS*EG1B	5	746.2	247
RIVER BEND SAT	1EGS*EG1A	2	786.75	299
Totals:		Sum: 7	Avg: 766.48	Avg: 273

02-310A 4.1 Crankshaft **Manf Recom O/H Hrs:** infinite

Measure diameter of crankpin journals(River Bend only)

RIVER BEND SAT	1EGS*EG1B	2	746.2	247
RIVER BEND SAT	1EGS*EG1A	2	786.75	299
Totals:		Sum: 4	Avg: 766.48	Avg: 273

02-315A 2 Cylinder Block **Manf Recom O/H Hrs:** infinite

Perform visual inspection for cracks

GRAND GULF SAT	1B/DIV 2	18	1454	605
TU ELECTRIC SAT	1EG2	2	640	126
DPC CATAWBA SAT	1A	5	1496	858
DPC CATAWBA SAT	2A	6	793	607
GRAND GULF SAT	1A/DIV I	24	2148	712
TU ELECTRIC SAT	1EG1	2	780	122
VOGTLE SAT	2A	4	673	180

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Results of Inspection for TDI D/G Phase I Components

Component No.	PM No.	Utility Results	D/G Train	No. Inspections	Run Hours	No. Starts
		DPC CATAWBA SAT	2B	4	796	652
		TU ELECTRIC SAT	1EG1	3	678	99
		VOGTLE SAT	1A	6	866	237
		VOGTLE SAT	2B	4	673	133
		DPC CATAWBA SAT	1B	8	1436	931
		RIVER BEND SAT	1EGS*EG1B	1	746.2	247
		RIVER BEND SAT	1EGS*EG1A	2	907.5	366
		CP&L SAT	1DG E002	32	891	426
		TU ELECTRIC SAT	1EG2	2	790	146
		VOGTLE SAT	1B	6	852	236
		Totals:		**Sum:** 129	**Avg:** 977.63	**Avg:** 393.1
02-315C	1	Cylinder Liners		**Manf Recom O/H Hrs:**	55,000	
Perform a visual inspection of liners for progressive wear.						
		DPC CATAWBA SAT	1B	64	1436	931
		VOGTLE SAT	1B	48	852	236
		CP&L SAT	1DG E003	80	615	325
		DPC CATAWBA SAT	2A	80	793	679
		DPC CATAWBA SAT	2B	64	792	652
		GRAND GULF SAT	1A/DIV I	64	2148	712

12/5/93 **Results of Inspection for TDI D/G Phase I Components**

Component No.	PM No.	Utility Results	D/G Train	No. Inspections	Run Hours	No. Starts
		TU ELECTRIC SAT	1EG2	16	790	146
		GRAND GULF SAT	1B/DIV 2	64	1454	605
		TU ELECTRIC SAT	1EG1	16	678	99
		CP&L SAT	1DG E002	80	891	426
		VOGTLE SAT	1A	48	866	237
		RIVER BEND SAT	1EGS*EG1A	18	907.5	366
		VOGTLE SAT	2A	32	673	180
		TU ELECTRIC 2 liners replaced due to scuffing	1EG1	16	780	122
		VOGTLE SAT	2B	32	673	133
		PERRY SAT	1R43C001A/ 1R43C001B	6	300	190
		RIVER BEND SAT	1EGS*EG1B	16	746.2	247
		TU ELECTRIC SAT	1EG2	16	640	126
		DPC CATAWBA SAT	1A	80	1496	858
		Totals:		**Sum:** 840	**Avg:** 922.67	**Avg:** 382.6

02-340A-B 1 Connecting Rods, Bushings, and Beari **Manf Recom O/H Hrs:** ROD/50000/Bush 35000/Brg25000

Inspect and measure all connecting rod bearing shells to verify lube maintennace.

Component No.	PM No.	Utility Results	D/G Train	No. Inspections	Run Hours	No. Starts
		RIVER BEND SAT	1EGS*EG1A	4	786.75	299
		RIVER BEND	1EGS*EG1B	2	746.2	247
		Totals:		**Sum:** 6	**Avg:** 766.48	**Avg:** 273

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Results of Inspection for TDI D/G Phase I Components

Component No.	PM No.	Utility Results	D/G Train	No. Inspections	Run Hours	No. Starts
02-340A-B	2	Connecting Rods, Bushings, and Beari	Manf Recom O/H Hrs:		ROD/50000/Bush 35000/Brg25000	
Inspect and measure the connecting rods. (2 for DSR's)						
		RIVER BEND SAT	1EGS*EG1A	2	786.75	299
		RIVER BEND	1EGS*EG1B	2	746.2	247
		Totals:		Sum: 4	Avg: 766.48	Avg: 273
02-340A-B	4	Connecting Rods, Bushings, and Beari	Manf Recom O/H Hrs:		ROD/50000/Bush 35000/Brg25000	
All connecting rod bolts, nuts, and washers should be visually inspected, and damaged parts should be replaced. The bolts should be MT inspected.						
		RIVER BEND SAT	1EGS*EG1B	36	746.2	247
		RIVER BEND SAT	1EGS*EG1A	16	786.75	299
		Totals:		Sum: 52	Avg: 766.48	Avg: 273
02-340A-B	5	Connecting Rods, Bushings, and Beari	Manf Recom O/H Hrs:		ROD/50000/Bush 35000/Brg25000	
During any disassembly that exposes the inside diameter of a rod-eye(piston pin) bushing, the surface of the bushing should be LP inspected to verify the continued abscence of linear indications in the heavily loaded zone widty +\-15 degrees of the bottom dead center position.						
		RIVER BEND SAT	1EGS*EG1A	2	786.75	299
		RIVER BEND SAT	1EGS*EG1B	2	746.2	247
		Totals:		Sum: 4	Avg: 766.48	Avg: 273
02-340A/B	1	Connecting Rods, Bushings and Bearin	Manf Recom O/H Hrs:		Rod50000/Bush 35000/Brg25000	
Inspect and measure all connecting rod bearing shells to verify lube oil maintenance, which affects wear rate						
		DPC CATAWBA SAT	2A	8	793	679
		TU ELECTRIC SAT	1EG1	1	678	99
		GRAND GULF SAT	1B/DIV 2	8	1077	345
		GRAND GULF SAT	1A/DIV I	10	2021	656
		DPC CATAWBA	2B	4	792	652

Results of Inspection for TDI D/G Phase I Components

Component No.	PM No.	Utility Results	D/G Train	No. Inspections	Run Hours	No. Starts
		SAT				
		VOGTLE SAT		3	852	236
		CP&L SAT	1DG E002	5	891	426
		PERRY SAT	1R43C001A/ 1R43C001B	3	530	310
		DPC CATAWBA SAT	1A	4	1496	858
		DPC CATAWBA SAT	1B	4	1436	931
		CP&L SAT	1DG E003	5	615	325
		Totals:		Sum: 55	Avg: 1016.5	Avg: 501.5

02-340A/B 10 Connecting Rods, Bushings and Bearin **Manf Recom O/H Hrs:** Rod50000/Bush 35000/Brg25000

All connecting rod bolts should be visually inspected for thread damage (galling) and the two pairs of bolts above the cramkpin should be MT inspected to verify the absence of cracking. All washers used with the bolts should be examined visually for

Component No.	PM No.	Utility Results	D/G Train	No. Inspections	Run Hours	No. Starts
		CP&L SAT	1DG E003	50	615	325
		GRAND GULF SAT	1B/DIV 2	48	1454	606
		GRAND GULF SAT	1A/DIV I	60	2148	712
		DPC CATAWBA SAT	2B	12	792	652
		DPC CATAWBA SAT	1B	24	1436	931
		CP&L SAT	1DG E002	30	725	356
		TU ELECTRIC SAT	1EG1	6	678	99
		PERRY SAT	1R43C001A/ 1R43C001B	12	530	310
		VOGTLE SAT	1B	18	852	236

Results of Inspection for TDI D/G Phase I Components

Component No.	PM No.	Utility Results	D/G Train	No. Inspections	Run Hours	No. Starts
		DPC CATAWBA SAT	1A	12	1496	858
		DPC CATAWBA SAT	2A	18	793	679
		Totals:		Sum: 290	Avg: 1047.2	Avg: 523.8

02-340A/B 11 Connecting Rods, Bushings and Bearin **Manf Recom O/H Hrs:** Rod50000/Bush 35000/Brg25000

A visual inspection should be performed of all external surfaces of the link rod box to verify the absence of any signs of service induced distress.

Utility Results	D/G Train	No. Inspections	Run Hours	No. Starts
DPC CATAWBA SAT	1B	8	1436	931
GRAND GULF SAT	1B/DIV 2	8	1454	605
DPC CATAWBA SAT	2B	4	792	652
DPC C[illegible] SAT	2A	6	793	679
CP&L SAT	1DG E002	5	891	426
PERRY SAT	1R43C001A/ 1R43C001B	2	530	310
TU ELECTRIC SAT	1EG1	1	678	99
VOGTLE SAT	1B	3	852	236
DPC CATAWBA SAT	1A	4	1496	858
CP&L SAT	1DC [illegible]	5	615	325
GRAND GULF SAT	1A/DIV 1	10	2148	712
Totals:		Sum: 56	Avg: 1062.3	Avg: 530.3

02-340A/B 12 Connecting Rods, Bushings and Bearin **Manf Recom O/H Hrs:** Rod50000/Bu[illegible]000/Brg25000

All of the bolt holes in the link rod box should be inspected for thread damage (galling) or other signs of abnormalities. Bolt holes subject to the highest stresses (the pair immediately above the crankpin) should be examined with a proper

Utility Results	D/G Train	No. Inspections	Run Hours	No. Starts
CP&L SAT	1DG E003	30	615	325

Results of Inspection for TDI D/G Phase I Components

Component No.	PM No.	Utility Results	D/G Train	No. Inspections	Run Hours	No. Starts
		GRAND GULF SAT	1B/DIV 2	8	1454	605
		GRAND GULF SAT	1A/DIV I	10	2148	712
		DPC CATAWBA SAT	2B	4	792	652
		DPC CATAWBA SAT	1B	8	1436	931
		CP&L SAT	1DG E002	30	891	426
		DPC CATAWBA SAT	1A	4	1496	858
		PERRY SAT	1R43C001A/ 1R43C001B	2	530	310
		VOGTLE SAT	1B	3	852	236
		TU ELECTRIC SAT	1EG1	1	678	99
		DPC CATAWBA SAT	2A	6	793	679
		Totals:		**Sum:** 106	**Avg:** 1062.3	**Avg:** 530.3

02-340A/B 2 Connecting Rods. Bushings and Bearin **Manf Recom O/H Hrs:** Rod50000/Bush 35000/Brg25000

Inspect and measure the connecting rods. Note. Perform inspection and measure for DSRVs and two for DSRs at random at one time 5-year inspection.

		DPC CATAWBA SAT	2B	4	792	652
		CP&L SAT	1DG E003	10	615	325
		GRAND GULF NA	1A/DIV I	10	2148	712
		DPC CATAWBA SAT	2A	9	793	607
		DPC CATAWBA SAT	1A	4	1496	858
		DPC CATAWBA SAT	1B	8	1436	931

Results of Inspection for TDI D/G Phase I Components

Component No.	PM No.	Utility Results	D/G Train	No. Inspections	Run Hours	No. Starts
		VOGTLE SAT	1B	3	852	236
		GRAND GULF SAT	1B/DIV 2	8	1454	606
		CP&L SAT	1DG E002	10	891	426
		PERRY SAT	1R43C001A/ 1R43C001B	2	530	310
		Totals:		**Sum:** 68	**Avg:** 1100.7	**Avg:** 566.2

02-340A/B **4** Connecting Rods, Bushings and Bearin **Manf Recom O/H Hrs:** Rod50000/Bush 35000/Brg25000

All connecting rod bolts, nuts, and washers should be visually inspected and damaged parts should be replaced. The bolts should be MT inspected to verify the continued absence of cracking. No detectable cracks should be allowed at the root of the threads.

GRAND GULF SAT	1A/DIV I	60	2148	712
CP&L SAT	1DG E002	30	891	426
GRAND GULF SAT	1B/DIV 2	48	1454	606
DPC CATAWBA SAT	2B	12	609	652
DPC CATAWBA SAT	2A	18	633	607
DPC CATAWBA SAT	1B	24	681	775
TU ELECTRIC SAT	1EG1	6	678	99
PERRY SAT	1R43C001A/ 1R43C001B	2	530	310
VOGTLE SAT	1B	18	852	236
DPC CATAWBA SAT	1A	12	605	739
CP&L SAT	1DG E003	30	615	325
Totals:		**Sum:** 260	**Avg:** 881.45	**Avg:** 498.7

12/5/93

Results of Inspection for TDI D/G Phase I Components

Component No.	PM No.	Utility Results	D/G Train	No. Inspections	Run Hours	No. Starts
02-340A/B	5	Connecting Rods, Bushings and Bearin	Manf Recom O/H Hrs:		Rod50000/Bush 35000/Brg25000	
During any disassemble that exposed the inside diameter of a rod-eye (piston pin) bushing, the surface of the bushing should be LP inspected to verify the continued absence of linear indications in the heavily loaded zone width +/-15 degrees of the bottom						
		DPC CATAWBA SAT	1A	4	605	739
		GRAND GULF SAT	1A/DIV 1	10	2148	712
		GRAND GULF SAT	1B/DIV 2	8	1454	605
		DPC CATAWBA SAT.	2A	6	633	607
		DPC CATAWBA SAT	2B	4	609	652
		DPC CATAWBA SAT	1B	8	681	775
		CP&L SAT	1DG E002	10	891	426
		VOGTLE SAT	1B	6	852	236
		PERRY SAT	1R43C001A/ 1R43C001B	2	530	310
		TU ELECTRIC SAT	1EG1	1	678	99
		CP&L SAT	1DG E003	10	615	325
		Totals:		**Sum:** 69	**Avg:** 881.45	**Avg:** 498.7
02-340A/B	6	Connecting Rods, Bushings and Bearin	Manf Recom O/H Hrs:		Rod50000/Bush 35000/Brg25000	
Measure the clearance between the link pin and link rod. Theis clearance should be zero; i.e., no measurable clearance when the specified bolt torque of 1,050 ft-lbs is applied.						
		TU ELECTRIC SAT	1EG1	1	678	99
		DPC CATAWBA SAT.	1A	16	800	66
		CP&L SAT	1DG E003	19	615	325
		DPC CATAWBA	1B	16	775	156

Results of Inspection for TDI D/G Phase I Components

Component No.	PM No.	Utility Results	D/G Train	No. Inspections	Run Hours	No. Starts
		SAT				
		GRAND GULF SAT.	1A/DIV I	10	2148	712
		GRAND GULF SAT	1B/DIV 2	8	1454	605
		CP&L SAT	1DG E002	21	891	426
		VOGTLE SAT	1B	3	852	236
		Totals:		Sum: 94	Avg: 1026.6	Avg: 328.1

02-340A/B 7 Connecting Rods, Bushings and Bearin **Man' Recom O/H Hrs:** Rod50000/Bush 35000/Brg25000

At the overhaul, visually inspect the rack teeth surfaces for signs of fretting and at one time 5-year inspection for rods disassembled.

		DPC CATAWBA SAT	1A	4	1496	858
		GRAND GULF SAT	1B/DIV 2	8	1454	605
		GRAND GULF SAT.	1A/DIV I	10	2148	712
		DPC CATAWBA SAT	2B	4	792	652
		DPC CATAWBA SAT	2A	6	793	679
		CP&L SAT	1DG E003	6	615	325
		TU ELECTRIC SAT	1EG1	1	678	99
		PERRY SAT	1R43C001A/ 1R43C001B	3	530	310
		VOGTLE SAT	1B	3	852	236
		CP&L SAT	1DG E002	10	891	426
		DPC CATAWBA SAT	1B	8	1436	931

Results of Inspection for TDI D/G Phase I Components

Component No.	PM No.	Utility Results	D/G Train	No. Inspections	Run Hours	No. Starts
		Totals:		Sum: 63	Avg: 1062.3	Avg: 530.3

02-340A/B 8 Connecting Rods, Bushings and Bearin **Manf Recom O/H Hrs:** Rod50000/Bush 35000/Brg25000

Inspect mating surfaces to verify that the minimum manufacturers recommended percent contact surface is available.

DPC CATAWBA SAT	1B	16	755	156
PERRY SAT	1R43C001A/ 1R43C001B	3	530	310
GRAND GULF SAT	1B/DIV 2	8	1454	606
GRAND GULF SAT	1A/DIV I	10	2148	712
CP&L SAT	1DG E002	4	891	426
VOGTLE SAT	1B	3	852	236
DPC CATAWBA SAT	1A	16	800	66
CP&L SAT	1DG E003	6	615	325
Totals:		Sum: 66	Avg: 1005.6	Avg: 354.5

02-340A/B 9 Connecting Rods, Bushings and Bearin **Manf Recom O/H Hrs:** Rod50000/Bush 35000/Brg25000

If connecting rod bolt stretch was measured ultrasonically during reassembly following the preservice inspection, the lengths of the two pair of bolts above the crankpin should be remeasured ultrasonically before the link rod box is disassembled.

DPC CATAWBA SA	2B	192	792	652
GRAND GULF SAT	1A/DIV I	60	2148	712
DPC CATAWBA No loose or cracked fasteners found.	2A	192	793	679
DPC CATAWBA SAT	1B	288	1436	931
CP&L SAT	1DG E003	6	615	325
VOGTLE SAT	1B	18	852	236

Results of Inspection for TDI D/G Phase I Components

Component No.	PM No.	Utility Results	D/G Train	No. Inspections	Run Hours	No. Starts
		DPC CATAWBA SAT	1A	480	1496	858
		TU ELECTRIC SAT	1EG1	6	678	99
		GRAND GULF SAT	1B/DIV 2	48	1454	605
		Totals:		Sum: 1290	Avg: 1140.4	Avg: 566.3
02-341A	1	Pistons		Manf Recom O/H Hrs:	60000	
Inspect and measure skirt and piston pin. This item assumes that AE skirts are installed. For other types, see site-specific recommendations.						
		CP&L SAT	1DG E002	10	891	426
		GRAND GULF SAT	1B/DIV 2	16	1454	605
		DPC CATAWBA SAT.	2A	4	633	607
		DPC CATAWBA SAT	2B	8	609	652
		CP&L SAT	1DG E003	10	615	325
		PERRY SAT	1R43C001A/ 1R43C001B	4	575	219
		DPC CATAWBA SAT	1B	8	681	775
		RIVER BEND SAT	1EGS*EG1A	2	786.75	299
		DPC CATAWBA SAT	1A	4	606	739
		PERRY SAT	1R43C001A/ 1R43C001B	4	530	310
		RIVER BEND SAT	1EGS*EG1B	2	746.2	247
		GRAND GULF SAT	1A/DIV I	16	2298	805
		VOGTLE SAT	1B	3	852	236

12/5/93

Results of Inspection for TDI D/G Phase I Components

Component No.	PM No.	Utility Results	D/G Train	No. Inspections	Run Hours	No. Starts
		Totals:		Sum: 91	Avg: 867.38	Avg: 480.4
02-360A	1	Cylinder Head		Manf Recom O/H Hrs:	35000	
Visually inspect cylinder heads (all cylinders)						
		PERRY SAT	1R43C001A/ 1R43C001B	6	530	310
		GRAND GULF SAT	1B/DIV 2	16	1077	345
		GRAND GULF SAT	1A/DIV I	16	2148	712
		GRAND GULF SAT	1A/DIV I	20	1710	433
		DPC CATAWBA SAT	2B	64	792	652
		DPC CATAWBA SAT	2A	80	793	679
		CP&L SAT	1DG E002	22	891	426
		RIVER BEND SAT	1EGS*EG1B	8	746.2	247
		CP&L SAT	1DG E003	7	615	325
		RIVER BEND SAT	1EGS*EG1A	16	786.75	366
		TU ELECTRIC SAT	1EG2	16	790	146
		TU ELECTRIC SAT	1EG1	16	780	122
		DPC CATAWBA SAT	1B	80	1436	931
		TU ELECTRIC SAT	1EG1	16	678	99
		DPC CATAWBA SAT	1A	80	1496	858
		TU ELECTRIC SAT	1EG2	16	640	126

Results of Inspection for TDI D/G Phase I Components

Component No.	PM No.	Utility Results	D/G Train	No. Inspections	Run Hours	No. Starts
		VOGTLE SAT	1B	9	852	236
		Totals:		**Sum:** 488	**Avg:** 985.94	**Avg:** 412.5

02-365C 2 Fuel Injection Tubing **Manf Recom O/H Hrs:** 35000

Visually inspect tubing lengths for fuel oil leaks or cracks if tubing is not shrouded. If shrouded, fuel oil leakage can be detected at the leak-off ports in the base nuts, which are provided for this purpose, or by annunciator if so equipped.

VOGTLE Some leaks, no impact on engine performance. SAT	2B	32	560	133
RIVER BEND SAT	1EGS*EG1A		907.5	366
GRAND GULF SAT	1B/DIV 2	56	1077	345
GRAND GULF SAT	1A/DIV1	56	1710	433
CP&L SAT	1DG E003	1000	615	325
VOGTLE Some leaks, no impact on engine performance. SAT	1B	48	852	236
TU ELECTRIC SAT	1EG2	27	790	146
PERRY Replaced with shrouded tubing. A few leaks on unshrouded tubes. SAT	1R43C001A	16	211	115
TU ELECTRIC SAT	1EG2	27	640	126
DPC CATAWBA One failed fuel line was replaced, one leak was found. No impact on engine performance	1A	667	696	792
TU ELECTRIC SAT	1EG1	27	678	99
TU ELECTRIC SAT	1EG1	20	780	122
VOGTLE Some leaks, no impact on engine performance. SAT	1A	48	866	237
DPC CATAWBA One failed fuel line was replaced, one leak was found. No impact on engine performance	1B	737	681	775
PERRY Replaced with shrouded tubing. A few leaks on unshrouded tubes. SAT	1R43C001B	16	160	154

12/5/93

Results of Inspection for TDI D/G Phase I Components

Component No.	PM No.	Utility Results	D/G Train	No. Inspections	Run Hours	No. Starts
		CP&L SAT	1DG E002	1000	891	426
		Totals:		**Sum:** 3777	**Avg:** 757.16	**Avg:** 301.9
02-390C	2	Push Rods		**Manf Recom O/H Hrs:**	100000	
		RIVER BEND SAT	1EGS*EG1A	48	907.5	366
		CP&L SAT	1DG E002	44	891	426
		CP&L SAT	1DG E003	22	615	325
		GRAND GULF SAT	1B/DIV 2	2	1077	345
		Totals:		**Sum:** 116	**Avg:** 872.63	**Avg:** 365.5
02-390G	1	Rocker Arm Capscrews, Drive Studs		**Manf Recom O/H Hrs:**		
Verify capscrew torque values						
		GRAND GULF SAT	1B/DIV 2	2	1077	345
		CP&L SAT	1DG E003	6	615	325
		VOGTLE SAT	2B	2	560	133
		VOGTLE SAT	2A	4	673	180
		VOGTLE SAT	1B	9	852	236
		VOGTLE SAT	1A	6	866	237
		PERRY SAT	1R43C001A/ 1R43C001B	40	530	310
		CP&L SAT	1DG E002	22	891	426
		Totals:		**Sum:** 91	**Avg:** 758	**Avg:** 274

12/5/93

Results of Inspection for TDI D/G Phase I Components

Component No.	PM No.	Utility Results	D/G Train	No. Inspections	Run Hours	No. Starts
02-390G	2	Rocker Arm Capscrews, Drive Studs		**Manf Recom O/H Hrs:**		
Verify that rocker arm drive studs are intact and tight.						
		CP&L SAT	1DG E003	80	615	325
		GRAND GULF SAT	1B/DIV 2	2	1077	345
		VOGTLE SAT	1A	6	866	237
		VOGTLE SAT	2A	4	673	180
		VOGTLE SAT	2B	2	560	133
		VOGTLE SAT	1B	9	852	236
		CP&L SAT	1DG E002	80	891	426
		Totals:		**Sum:** 183	**Avg:** 790.57	**Avg:** 268.9
03-365C	2	Fuel Injector Tubing		**Manf Recom O/H Hrs:**		
		RIVER BEND SAT	1EGS*EG1B		746.2	247
		Totals:		**Sum:**	**Avg:** 746.2	**Avg:** 247
MP-022/23	2	Turbocharger		**Manf Recom O/H Hrs:**	8000-10000	
Inspect impeller/diffuser and clean if necessary						
		TU ELECTRIC SAT	1EG2	1	150	20
		DPC CATAWBA SAT	1B	10	136	155
		GRAND GULF SAT	1B/DIV 2	3	1275	490
		GRAND GULF SAT	1A/DIV I	4	2148	712
		DPC CATAWBA SAT	2B	8	152	163

Results of Inspection for TDI D/G Phase I Components

Component No.	PM No.	Utility Results	D/G Train	No. Inspections	Run Hours	No. Starts
		DPC CATAWBA SAT	2A	8	181	174
		VOGTLE SAT	1B	2	852	236
		RIVER BEND SAT	1EGS*EG1A	1	443.75	299
		TU ELECTRIC SAT	1EG1	1	678	99
		DPC CATAWBA SAT	1A	10	139	158
		CP&L SAT	1DG E003	4	615	325
		RIVER BEND SAT	1EGS*EG1B	1	451.2	247
		PERRY SAT	1R43C001A/ 1R43C001B	2	190	120
		Totals:		**Sum:** 56	**Avg:** 570.07	**Avg:** 246

MP-022/23 **3** Turbocharger **Manf Recom O/H Hrs:** 8000-10000

Measure rotor end play (axial clearance) to identify trends of increasing clearance (i.e., thrust bearing degrtation.

VOGTLE SAT	1B	6	852	236
GRAND GULF SAT	1B/DIV 2	8	1364	543
GRAND GULF SAT	1A/DIV I	8	2148	712
DPC CATAWBA SAT	2B	8	152	163
DPC CATAWBA SAT	2A	8	181	174
DPC CATAWBA SAT	1B	10	136	155
PERRY SAT	1R43C001A/ 1R43C001B	11	90	40
CP&L SAT	1DG E002	12	891	426

12/5/93

Results of Inspection for TDI D/G Phase I Components

Component No.	PM No.	Utility Results	D/G Train	No. Inspections	Run Hours	No. Starts
		VOGTLE SAT	2A	4	673	180
		VOGTLE SAT	2B	4	560	133
		TU ELECTRIC SAT	1EG2	1	150	20
		TU ELECTRIC SAT	1EG2	1	790	146
		TU ELECTRIC SAT	1EG1	1	678	99
		DPC CATAWBA SAT	1A	10	139	158
		VOGTLE SAT	1A	6	866	237
		CP&L SAT	1DG E002	10	615	325
		Totals:		**Sum:** 108	**Avg:** 642.81	**Avg:** 234.2
MP-022/23	4	Turbocharger		**Manf Recom O/H Hrs:**	8000-10000	
Perform visual and blue check inspections of the thrust bearing						
		DPC CATAWBA SAT	2A	8	181	174
		DPC CATAWBA SAT	2B	8	152	163
		CP&L SAT	1DG E003	4	615	325
		GRAND GULF SAT	1A/DIV I	4	2148	712
		RIVER BEND SAT	1EGS*EG1A	1	443.75	299
		DPC CATAWBA SAT	1B	10	136	156
		GRAND GULF SAT	1B/DIV 2	4	1364	543
		VOGTLE SAT	1B	2	852	236

Results of Inspection for TDI D/G Phase I Components

Component No.	PM No.	Utility Results	D/G Train	No. Inspections	Run Hours	No. Starts
		TU ELECTRIC SAT	1EG1	1	678	99
		DPC CATAWBA SAT	1A	10	139	158
		RIVER BEND SAT	1EGS*EG1B	1	451.2	247
		CP&L SAT	1DG E002	5	891	426
		TU ELECTRIC SAT	1EG2	1	790	146
		PERRY SAT	1R43C001A/ 1R43C001B	2	190	120
		Totals:		Sum: 61	Avg: 645.07	Avg: 271.6
MP-022/23 Disassemble, inspect, and refurbish	5	Turbocharger		Manf Recom O/H Hrs:	8000-10000	
		DPC CATAWBA SAT	1B	10	136	155
		GRAND GULF SAT	1B/DIV 2	4	1364	543
		GRAND GULF SAT	1A/DIV I	2	2148	712
		DPC CATAWBA SAT	2A	8	181	174
		RIVER BEND SAT	1EGS*EG1A	1	443.75	299
		PERRY SAT	1R43C001A/ 1R43C001B	2	190	120
		CP&L SAT	1DG E002	4	725	355
		TU ELECTRIC SAT	1EG2	1	790	146
		TU ELECTRIC SAT	1EG1	1	678	99
		DPC CATAWBA SAT	1A	10	139	158

12/5/93

Results of Inspection for TDI D/G Phase I Components

Component No.	PM No.	Utility Results	D/G Train	No. Inspections	Run Hours	No. Starts
		SAT				
		TU ELECTRIC	1EG2	1	790	146
		SAT				
		TU ELECTRIC	1EG1	1	678	99
		SAT				
		DPC CATAWBA	1A	10	139	158
		One missing vane was discovered on the right bank turbo during one inspection but there have been no instances of catastrophic turbo failures due to this condition.				
		CP&L	1DG E002	4	391	426
		SAT				
		RIVER BEND	1EGS*EG1B	2	451.2	247
		SAT				
		Totals:		Sum: 70	Avg: 558.70	Avg: 227.2

SUMMARY OF OWNER"S TECHNICAL SPECIFICATION REQUIREMENTS EDG

ATTACHMENT 4

PLANT	TECH SPEC WORDING	PARA/PG
Harris	"Subjecting the diesel to an inspection in accordance with procedures prepared in accordance with the TDI Owners Group recommendations for this class of standby service."	4.8.1.1.2.f.1 Pg. 3/4 8-6
Comanche Peak	"Subjecting the diesel to an inspection in accordance with procedures prepared in conjunction with its manufacturer's recommendations for this class of standby service; "	4.8.1.1.2.f.1 Pg. 3/4 8-7
CNS	"Subjecting the diesel to an inspection, during shutdown, in accordance with procedures prepared in conjunction with its manufacturer's recommendations for this class of standby service;"	g.1 Pg. 3/4 8-5
River Bend	"Subjecting the diesel to an inspection in accordance with procedures prepared in conjunction with its manufacturer's recommendations for this class of standby service; "	f.1 Pg. 3/4 8-6
Vogtle	"Subjecting the diesel to an inspection in accordance with procedures prepared in conjunction with its manufacturer's recommendations for this class of standby service; "	4.8.1.1.2.h.1
Grand Gulf	"Subjecting the diesel to an inspection in accordance with procedures prepared in conjunction with its manufacturer's recommendations for this class of standby service; "	4.8.1.1.2.d.1
Perry	"Subjecting the diesel generator to an inspection prepared in conjunction with its manufacturer's recommendations for this class of service."	f.1 Pg. 3/4 8-5

DE&S
Duke Engineering & Services

230 South Tryon Street
P.O. Box 1004
Charlotte, NC 28201-1004

(704) 382-9800 Bus
(704) 382-8389 Fax

December 21, 1993

Mr. James A. Norberg, Chief
Mechanical Engineering Branch
Nuclear Regulatory Commission
Washington, DC 20555

Subject: Cooper-Enterprise (TDI) Owners Group
Generic Licensing Submittal for Emergency Diesel
Generators Conditions of License for
Utilities with Enterprise Engines
File: MTS-4086

Dear Mr. Norberg:

During the December 14, 1993 meeting with the TDI Owners Group regarding their Supplement 2 submittal dated 12/7/93 two areas where additional information was needed were identified. Comments addressing these areas are provided below:

1. Available Outage Windows for Teardowns/Overhauls: The available "windows" of outage time of sufficient length to allow engine teardowns and/or overhauls are being shortened due to Shutdown Risk Management requirements which have been imposed. The actual window available where a diesel can be removed from service for maintenance depends on a number of factors including plant design, availability of alternate power sources, fuel handling schemes (e.g. is core completely off loaded for shuffle) and other plant operations, maintenance or inspection requirements. These factors cause the window to vary from outage to outage. Typically the available window is between 10 and 21 days. Shutdown Risk Management programs have compressed this window. Again, due to the factors which affect the available window the impact of this program varies. In some cases it will shorten the window by as much as 20%. As a result of this shortening and varying lengths of available windows all plants need maximum flexibility in scheduling diesel work (i.e. schedule major diesel work during outage where longer window are available without impacting overall outage length). Time directed teardowns/overhauls do not allow this flexibility.

2. Fast Start: All licensees have the authority to delete fast start requirements based on Generic Letter 84-15. Many utilities have not taken this step. There are a number of reasons for this. First, many engines have control systems which will not allow a slow start. Some of the TDI owners are developing a new control system design to address this situation. Second, many utilities want to consolidate all changes for a particular technical specification. This is due to the impact on the utility and the NRC work load resulting from a technical specification change request. Most utilities are waiting for the Generic letter addressing accelerated testing of

emergency diesels before requesting a change to their technical specifications. When both of these issues are addressed (fast starts and accelerated testing) nuclear engines starting and operation will be similar to commercial engines. In fact, with respect to number of starts, many commercial engines used in peaking service have logged significantly more starts than the typical engine in nuclear service (typically these engines start twice each day). These commercial engines have reported no significant shortening in the life of components as result of this large number of starts. Once the slow start option is implemented and accelerated testing is eliminated, commercial engine operation will closely match that of engines in nuclear service and expected component life should compare favorably with commercial engine components. However, inspection results to date have shown that component life expectancy for engines in nuclear service is not significantly different from commercial engine components.

If there are any questins or comments, please contact Rick Deese (704) 875-4065 or Dick Day (704) 382-2763.

Sincerely,

RC Day

J. B. George, Chairperson
TDI Owners Group

for C. W. Hendrix, Jr., Project Manager
Duke Engineering & Services, Inc.

/rfm

cc:
- J. Rajan
- R. J. Deese
- R. C. Day
- G. A. Harrison
- Project File
- Central Records